MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 114 No. 3 1954

ANNUAL REPORT OF THE COUNCIL

Published and Sold by the

ROYAL ASTRONOMICAL SOCIETY

BURLINGTON HOUSE

LONDON, W. 1

Price Thirteen Shillings and Sixpence

NOTICE TO AUTHORS

1. *Communications.*—Papers must be communicated to the Society by a Fellow. They should be accompanied by a summary at the *beginning* of the paper conveying briefly the content of the paper, and drawing attention to important new information and to the main conclusions. The summary should be intelligible in itself, without reference to the paper, to a reader with some knowledge of the subject; it should not normally exceed 200 words in length. **Authors are requested to submit MSS. in duplicate. These should be typed using double spacing and leaving a margin of not less than one inch on the left-hand side. Corrections to the MSS. should be made in the text and not in the margin.** Unless a paper reaches the Secretaries more than seven days before a Council meeting it will not normally be considered at that meeting. By Council decision, MSS. of accepted papers are retained by the Society for one year after publication; unless their return is then requested by the author, they are destroyed.

2. *Presentation.*—Authors are allowed considerable latitude, but they are requested to follow the general style and arrangement of *Monthly Notices*. References to literature should be given in the standard form, including a date, for printing either as footnotes or in a numbered list at the end of the paper. Each reference should give the **name and initials** of the author cited, irrespective of the occurrence of the name in the text (some latitude being permissible, however, in the case of an author referring to his own work). The following examples indicate the style of reference appropriate for a paper and a book, respectively :—

A. Corlin, *Zs. f. Astrophys.*, **15**, 239, 1938.
H. Jeffreys, *Theory of Probability*, 2nd edn., section 5.45, p. 258, Oxford, 1948.

3. *Notation.*—For technical astronomical terms, authors should conform closely to the recommendations of Commission 3 of the International Astronomical Union (*Trans. I.A.U.*, Vol. VI, p. 345, 1938). Council has decided to adopt the I.A.U. 3-letter abbreviations for constellations where contraction is desirable (Vol. IV, p. 221, 1932). In general matters, authors should follow the recommendations in *Symbols, Signs and Abbreviations* (London : Royal Society, 1951) except where these conflict with I.A.U. practice.

4. *Diagrams.*—**These should be designed to appear upright on the page, drawn about twice the size required in print and prepared for direct photographic reproduction except for the lettering, which should be inserted in pencil. Legends should be given in the manuscript indicating where in the text the figure should appear.** Blocks are retained by the Society for 10 years; unless the author requires them before the end of this period they are then destroyed.

5. *Tables.*—**These should be arranged so that they can be printed upright on the page.**

6. *Proofs.*—Costs of alterations exceeding 5 per cent of composition must be borne by the author. Fellows are warned that such costs have risen sharply in recent years, and it is in their own and the Society's interests to seek the maximum conciseness and simplification of symbols and equations consistent with clarity.

7. *Revised Manuscripts.*—When papers are submitted in revised form it is especially requested that they be accompanied by the original MSS.

Reading of Papers at Meetings

8. When submitting papers authors are requested to indicate whether they will be willing and able to read the paper at the next or some subsequent meeting, and approximately how long they would like to be allotted for speaking.

9. Postcards giving the programme of each meeting are issued some days before the meeting concerned. Fellows wishing to receive such cards whether for Ordinary Meetings or for the Geophysical Discussions or both should notify the Assistant Secretary.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 114 No. 3

ANNIVERSARY MEETING OF 1954 FEBRUARY 12

Professor H. Dingle, Vice-President, in the Chair

The election by the Council of the following Fellows was duly confirmed :—

Charles Telford Britton, Department of Astronomy, University of Manchester (proposed by Z. Kopal) ;

George Allen Chisnall, Department of Astronomy, University of Manchester (proposed by Z. Kopal) ;

Philip Rowland Freshwater, 70 Wards Road East, Newbury Park, Ilford, Essex (proposed by A. C. Clarke) ;

Bevan Cecil Landseer-Jones, 50 Hans Place, London, S.W.1 (proposed by Sir David Brunt) ;

William George Herbert Tregear, 2 Morton Street, Glenbervie W.5, Melbourne, Victoria, Australia (proposed by C. S. Middleton) ; and

Albert York, 90 Boundary Road, Mortdale, Sydney, New South Wales, Australia (proposed by H. Wood).

The election by the Council of the following Junior Members was duly confirmed :—

Anthony Gerald Hearn, St. Catharine's College, Cambridge (proposed by J. V. Thomson) ;

Brian Lloyd Hewitt, 106 Cambridge Road, Southport, Lancashire (proposed by Z. Kopal) ; and

Thomas William Olle, 65 Barlton Road, Boston, Lincolnshire (proposed by Z. Kopal).

One hundred and thirteen presents were announced as having been received since the last meeting, including :—

C. A. Ronan, *The cometography of A. G. Pingré* (presented by the author) ; and

W. M. Smart, *Celestial mechanics* (presented by the author).

In the absence of the President, the Presidential Address on the award of the Gold Medal to Dr Walter Baade (see p. 370) was read by the Vice-President, Professor H. Dingle.

ANNUAL GENERAL MEETING OF 1954 FEBRUARY 12

Professor H. Dingle, Vice-President, in the Chair

The Minutes of the preceding Annual General Meeting were read, confirmed and signed.

The Vice-President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year.

The Secretary read extracts from the Narrative Report of the Council.

The Report of the Honorary Auditors was read (see p. 281).

The Treasurer gave a brief explanation of the accounts and a survey of the Society's financial position.

A vote of thanks to the Honorary Auditors of the Treasurer's accounts for 1953 was proposed and carried unanimously.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner together with the Report of the Auditors and the President's Address.

The Scrutineers reported to the Vice-President the result of the ballot, and the names of the Officers and Council elected for the ensuing year were read to the Meeting. (The list of names is given on p. 384.)

The thanks of the Society were given to the retiring Vice-President (Professor H. Dingle), Secretary (Miss F. M. McBain), and other members of Council.

The thanks of the Meeting were given to the Scrutineers of the ballot.

The Meeting then adjourned.

REPORT OF THE COUNCIL TO THE HUNDRED AND THIRTY-FOURTH ANNUAL GENERAL MEETING OF THE SOCIETY

This Report refers to the calendar year 1953

1. *Membership*.—The slow but steady increase in the Society's membership which has been a recurrent feature of these Reports in the post-war years continues. To some extent this no doubt reflects the interest taken in the Society's publications by increasing numbers of radio physicists and geophysicists, and offsets the mounting expenditure incurred on printing papers on radio astronomy and geophysical subjects. The table on p. 281 exhibits the present position.

The Society lost by death the following Associates:

William Snyder Eichelberger (1951)
Edwin Powell Hubble
Armin Otto Leuschner

and the following Fellows:

*Ernest William Barnes	*George Aimer Russell
*John Borthwick Dale	*Frank Sargent
Henry Howard Hammond	Wilfred Shaw
James Mason	*William Lisle Shepherd
*Forest Ray Moulton (1952)	*George Frederick Herbert Smith
*Asutosh Mukhopadhyay (1924)	Harold Henry Thorne

* Life Fellow.

Obituary notices of some of these appear on pp. 289–298.

2. *Finance*.—During the year it was necessary to increase substantially the insurances held by the Society in order to make the amounts covered adequate to present values. To offset, to some extent, the increased premiums, the Council has decided to print the full details of Gifts and Trusts quinquennially only, thus saving the cost of printing six pages of *Monthly Notices* four years out of five. The list following the Treasurer's accounts (pp. 282–285), however, will continue to commemorate annually the generosity of donors. This year it contains a new item: a bequest to the Society of £250 from the late Rev. Harold Pain for solar research.

Owing mainly to increased sales of publications and to a decrease in the printing bill (but not in printing charges) which is not expected to recur next year, there is a surplus of £462 for the year, compared with a deficit of £468 in the preceding year. On the other hand, the Society is again indebted to the Royal Society for the substantial allocation of £1000 from the Parliamentary Grant-in-Aid of Scientific Publications. A truer picture of the Society's finances will therefore be obtained by reflecting that were it not for this allocation and

one of £800 in the preceding year, a deficit of £1268 last year would have been followed by a present deficit of £538.

To aid progress towards a balance independent of such allocations is in the power of every non-compounding Fellow, any part of whose income is subject to the full standard rate of United Kingdom income tax, and that at no cost to himself. By paying his annual contribution under a seven-year covenant, he almost doubles its cash value to the Society. To remove misgivings, it may be said that such a covenant would lapse on death and so would not constitute a continuing liability.

During the year the scheme assuring a pension to the porter and his wife on retirement has been modified to bring it into line with the superannuation arrangements for the clerical staff. The modest increase of premium involved will provide a welcome increase of benefit for the domestic staff, who in the nature of things tend to enter the Society's service rather late in life.

The cost of providing services for our guest Societies has risen sharply in recent years. The new agreement made with the British Astronomical Association in 1951 took account of this factor; now the London Mathematical Society has agreed to increase its annual payment to the Society from £30 to £40.

3. *Meetings.*—Of the usual eight meetings held at Burlington House two were devoted to George Darwin Lectures: the postponed 1952 Lecture by Dr Hubble was delivered at the May meeting, and Professor Chandrasekhar gave the 1953 Lecture in November. The five Geophysical Discussions held during the year attracted good audiences, and a crowded joint meeting with the Royal Meteorological Society at the rooms of the latter on December 16 heard a lively discussion on Scintillation.

A large number of Fellows and their guests enjoyed the hospitality of the University of Durham and of the Newcastle Astronomical Society during the period July 20–23, when an Ordinary Meeting of the Society, an Astronomical Colloquium on the Design of Astronomical Instruments, and a Geophysical Discussion on the Age of the Earth were held at King's College, Newcastle upon Tyne. The Society is particularly indebted to Professor G. R. Goldsbrough and Mr R. Fallaw, in whose capable hands the local arrangements functioned with admirable smoothness; and to Professor W. M. Smart, who delivered a well-attended public lecture on The Origin of the Earth.

Astronomers from overseas who attended the Society's meetings included Dr C. S. Beals (Ottawa), Dr S. Herrick (California) and Monsieur P. Ledoux (Liège).

4. *Publications.*—During the year the following were published and distributed:

Monthly Notices, Vol. **112**, Nos. 4, 5, 6; Vol. **113**, Nos. 1, 2, 3.
Geophysical Supplement, Vol. **6**, Nos. 7, 8.
Occasional Notes, No. 14.

It is regretted that owing to a partial breakdown in the printers' arrangements for despatch, some copies of *Monthly Notices*, Vol. **113**, Nos. 2 and 3 went astray. A notice appearing with No. 4 invites Fellows to inspect their shelves to make sure that no copies are either missing or duplicated.

Also published during the year were a new version of Dreyer's *New General Catalogue* and *Index Catalogues* (reproduced by photolithography from the original *Memoirs* and bound into one volume) and a new edition of the *Catalogue of Slides and Prints* of celestial photographs in the Society's collection. A *General Index* of all the Society's publications for the period 1932–50 was in galley proof at the end of the year.

The President and General Secretary of the International Astronomical Union have invited the Society to print in the *Monthly Notices* Russian translations of the summaries of papers appearing therein. The Council has expressed its willingness to cooperate in any workable scheme whereby abstracts in different languages may be made available to foreign astronomers, but finds this particular proposal impracticable. An alternative scheme for attaining the desired end in what is believed to be a more efficient way has been suggested to the Officers of the International Astronomical Union and developments are awaited.

5. *Awards*.—The Gold Medal for 1953 went to Professor S. Chandrasekhar for his contributions to mathematical astrophysics. The presentation ceremony took place at the November meeting, after the Medallist had delivered his George Darwin Lecture.

The first award of the Eddington Medal was made to Canon Georges Lemaître for his work on the expansion of the Universe. Canon Lemaître was present at the Anniversary Meeting to receive his Medal, as was also Mr J. P. M. Prentice, who had been awarded the Jackson-Gwilt Medal and Gift for his contributions to the study of meteors.

Professor V. A. Ambartsumyan (Byurakan) and Professor A. Unsöld (Kiel) were elected Associates during the year.

6. *Library*.—Early in the year it became clear that the reorganization of the Library could not be completed by the scheduled date (August 31). After full discussion of the position, the Library Committee submitted to the Council a number of possible schemes, ranging from termination of the reorganization at the stage it would have reached at the end of August to retention of the services of the library staff until the work was completed. The Council took the view that library facilities are of such importance to Fellows that it would be false economy to interrupt the work before it was substantially complete. The Assistant Librarian was therefore offered and accepted re-appointment until 1954 May 31, and the Librarian until 1954 December 31; the intention being that Miss Wadsworth would train her successor in the duties of the post of Librarian after Mr Kenedy had left the Society's employment.

During the closing of the Library in August the periodicals were rearranged and placed in their permanent positions, mostly in the Upper Library. The Society's holdings of *Astronomische Nachrichten* were combined with the substantial runs of this periodical in the Kuffner Library, one complete set of volumes in good condition being retained. The remaining parts, comprising a complete set in less good condition and an incomplete set, have been sold for £400 and £200 respectively.

It is intended that the Catalogue, when completed, shall be microfilmed and the copy stored away from Burlington House. This will considerably simplify

claim procedure should part of the Library be destroyed by fire together with the Catalogue itself.

7. *The Society's premises.*—During the year the out-of-date kitchen range in the porter's quarters was removed and replaced by a modern slow-burning fire in a tiled surround.

Two table lamps have been provided to supplement the lighting in the main library, and exterior lights installed in the basement area.

Decorations outstanding on the top floor have been held over pending completion of the library reorganization.

Installation of a new revolving blackboard in the Meeting Room has more than doubled the writing area available to speakers. The initial cost of this board (though not of the installation or associated lighting) was equally shared between the Society and the London Mathematical Society.

8. *The Wilfred Hall Bequest.*—In the early part of the year the Council received an offer from the executors of the late Dr Wilfred Hall of his twin 15-inch equatorial telescope and accessories. Under the terms of the will the bequest was made first to the British Astronomical Association but that body, after careful consideration, had declined it. As a result of enquiries circulated to all astronomical institutions and other bodies thought likely to be interested in borrowing the telescope, negotiations were started in March with the Municipality of Preston, which already controls the Jeremiah Horrocks Observatory. An agreement has now been signed with the Preston Corporation by which the Society, having accepted the bequest, lends the instrument at once to the Corporation, which will re-erect it in a new building at Preston. The terms of the loan, whilst not committing the Society to any expenditure on the transaction, will, it is hoped, enable the telescope to enter on a new lease of useful life in Lancashire within a year or two.

9. *The Total Solar Eclipse of* 1954 *June* 30.—This eclipse will provide the best chance for many years for astronomers to see a total solar eclipse within easy reach of the United Kingdom. With the collaboration of the British Astronomical Association a joint committee has organized facilities for a party of some 150 Fellows and Members and their guests to see the eclipse from the west coast of Sweden, where the chance of fine weather is good. The party will travel by surface transport and be out of Great Britain for ten days. Tentative arrangements for air transport to the belt of totality and back in one day fell through for lack of support.

10. *The Isaac Newton Observatory.*—In order that Fellows may be kept informed of the progress of work on the Isaac Newton Observatory, the Council hopes to arrange each year to receive a report from one of its representatives on the Board of Management. Sir John A. Carroll has kindly supplied the first of these, as follows :

(*a*) *Optical design.*—The Board of Management of the Isaac Newton Telescope has agreed that it shall be a Schmidt with spherical primary and correcting plate for direct photography and for nebular spectroscopy at the prime focus. An aspherical Gregorian secondary will be used for spectrographic observations at the Coudé focus, with the correcting plate dismounted.

Optical figuring of the 98-inch spherical main mirror has progressed as fully as is practicable, pending testing the mirror on its final supporting system.

Tests of the mirror on edge (i.e. axis horizontal) show no unacceptable errors. The tests it has been possible to make would not, however, reveal some slight but unacceptable astigmatism and it is planned to test the mirror on its back (i.e. axis vertical) during the summer to examine its figure more completely. After correction of any significant errors then found any further testing and figuring will be with the mirror in its cell with the supporting system to be used in the actual telescope.

It is intended to order the glass for the correcting plate very shortly. An " ultra-violet " type of glass will be ordered, and delivery is expected some six months after placing the order.

(*b*) *Mechanical design.*—Very prolonged consideration has been given to a wide variety of mountings.

Among the systems considered and rejected is one in which the telescope is supported in a yoke axis, running east and west, and incorporating compensation for rotation of the field. The resulting simplification in mechanical features, though considerable, does not warrant the complications and probable high development cost of the driving system required.

Likewise a scheme to encase the telescope in an outer sheath, independently supported but moving with the telescope, thus eliminating the usual dome, has been considered and rejected.

Of the many possible variants of the equatorial mounting the Board of Management has resolved that two merit detailed design study. Both are off-axis forms, so that observations with the Coudé spectrograph can be made in all parts of the sky with the Coudé mirror fixed at an angle of 45° to the telescope axis with a second mirror on the polar axis inclined at 45° to both the declination and polar axes. One of these designs is closely similar to that used for the McDonald 82-inch reflector, which has the telescope mounted to one side of the polar axis and carried by a stub declination axis. In the other the telescope is mounted between stiff forks from the top of a truncated conical polar axis, but sufficiently off-axis for the second Coudé mirror to be placed on the polar axis, a counterweight being placed alongside the forks on the top of the polar axis. This latter design avoids the short stub declination axis of the McDonald design, which may not be mechanically satisfactory for so large a telescope (50-ft. long tube) as the Isaac Newton 98-inch. It appears to be satisfactory both mechanically and optically though unusual in appearance. It is expected that decision on the general features of mechanical design may be reached in May next.

For spectrographic observations at the Coudé focus aberrations increase so rapidly off the axis, because of the spherical figure of the primary mirror, that some method of maintaining the primary and secondary mirrors in precise alignment is essential since the tube cannot be intrinsically stiff enough to maintain the alignment within acceptable limits in all positions of the telescope.

This compensation could be made purely mechanically by imparting suitable displacements to the secondary mirror relative to the telescope tube. No correction of flexure is needed when the telescope is used as a Schmidt, and of course the actual form of the tube itself is irrevelant; it is merely a support for the corrector plate and auxiliary mirrors.

There is, however, an interesting possibility of using a notion due to Mr B. N. Wallis for removing the flexure of the tube itself. In this scheme the hollow members of the skeleton tube would contain oil under pressure. By varying the pressure differentially between the members it would be possible in principle to counteract automatically the small deflections from straightness to be expected as the telescope changes elevation. A study contract is proceeding to investigate the possibility and to provide a basis for assessing its complexity, reliability and cost as compared with straight mechanical compensation. A potential advantage is considerable lightening of the main tube, but the gain in lightening the whole moving system is naturally limited in any case by the size and weight of the optical system.

11. *Miscellaneous.*—The Society was allotted eight seats in Hyde Park for Fellows and their guests to view the Coronation procession. More applications were received than the number of seats available, and an allocation was made by ballot.

It is regrettable to have to report that planning of the Science Centre has been indefinitely deferred owing to the need for national economy. The London County Council has acquired the South Bank site, and the Ministry of Works is arranging for a lease to be granted as soon as conditions permit building; but the scheme has clearly suffered a crippling setback.

The Council has discussed the possibility of so arranging the Society's business that all Fellows resident overseas shall receive balloting lists in time to take part in the election of Officers and Council. With the present schedule of business and the present frequency of air mails it will almost always happen that balloting lists will reach overseas Fellows in time for them to be returned by air mail before the Annual General Meeting. The expense of despatch by air mail has not been thought justified to avoid the occasional late arrival of lists in Australia and New Zealand by surface mail.

A new film of solar prominences entitled " Action on the Sun " has been received from Professor D. H. Menzel, and copies are now available for loan to Fellows on the usual terms.

The President represented the Society at the centenary celebrations of the Royal Photographic Society on 1953 January 20.

Representatives of the Society were appointed during the year as follows :

on the National Oceanographic Council,
Dr R. Stoneley;
on the Board of Management of the Isaac Newton Observatory,
Professor W. H. McCrea;
on the Board of Visitors of the Royal Greenwich Observatory,
Sir Harold Jeffreys;
on the Board of Jodrell Bank Experimental Station,
Dr J. S. Hey.

REPORT OF THE HONORARY AUDITORS FOR THE YEAR 1953

We have examined the professionally audited accounts of the Society and have checked the official list of Fellows against subscriptions received. The membership continues to increase steadily and the number of Fellows in arrears has been substantially reduced.

We have examined the premises of the Society and note with satisfaction the redecoration of the second floor kitchen and the purchase of various items of equipment.

We acknowledge with gratitude the help and cooperation given us by the Assistant Secretary in providing the information that we required.

R. H. GARSTANG
M. J. SEATON

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Fellows: Compounders	Fellows: Annual Contributors	Junior Members	Associates	Total
1953 January 1	1	6	206	802	32	51	1098
Since elected		...	...	60	14	2	76
Junior Members elected to Fellowship ...		...	...	10	−10	...	0
Fellow re-elected		...	...	1	...	...	1
Deceased 1953		...	−6	−4	...	−3	−13
Deceased before 1953, notified in 1953 ...		...	−2	...	...	...	−2
Since compounded...		...	3	−3	...	...	0
Resigned 1953		...	...	−10	−2	...	−12
Names removed		...	...	−27	−3	...	−30
1954 January 1	1	6	201	829	31	50	1118

(N.B.—Twelve Associates are also Fellows, and are therefore counted twice in the above table.)

Dr. *General Fund Revenue Account*

	£	s.	d.	£	s.	d.	*1952* £
To Salaries and Wages, including Pension Premiums and National Insurance				2,086	15	6	*1,877*
,, Insurance and Telephone				51	13	9	*49*
,, Printing etc.							
Monthly Notices, Vol. 113	2,035	11	11				
Geophysical Supplement, Vol. 6, Nos. 7 and 8... ...	407	4	10				
Occasional Notes, Vol. 2, No. 15	110	0	0				
Photo-engraving	180	17	7				
New General Catalogue	399	0	0				
Paper Supply	404	5	5				
Miscellaneous printing and carriage	430	10	0				
General Index	200	0	0				
	4,167	9	9				*4,475*
Less Amount received for 1953 from the Parliamentary Grant-in-Aid for Scientific Publications through the Royal Society	1,000	0	0				*750*
				3,167	9	9	*3,725*
,, Posting and Packing				233	14	1	*247*
General Expenses :—							
Stationery and Office Expenses	99	2	3				
Lighting and Heating	206	1	7				
Travelling Expenses	26	10	2				
Subscriptions to National Central Library and A.S.L.I.B.	4	4	0				
Accountant's Fees	63	0	0				
Gold Medal	15	5	6				
Furniture and Fittings, including repairs	186	10	5				
I.A.U. Telegram Service	6	16	10				
House Expenses	103	0	5				
Meeting Expenses	60	11	3				
Library Expenses	37	2	2				
Sundries	49	12	0				
				857	16	7	*939*
,, Block Subscription to *The Observatory*				190	0	0	*190*
,, Purchase of Books from Potter Fund				13	2	1	*10*
,, Reserve for Repairs				300	0	0	*300*
,, Binding of Periodicals, etc.				86	4	9	*187*
,, Reproduction of Photographic Slides and Prints				194	4	2	*103*
,, Films, Hire and Expenses				20	17	3	*7*
,, Reprint Expenses				...			*7*
,, Newcastle Meeting Expenses				22	17	7	...
				7,224	15	6	*7,641*
,, **Surplus, one year to date (deficit in previous year)** ...				461	15	11	*−468*
				£7,686	11	5	*7,173*

INVESTMENTS

As at 1953 December 31

General Fund

£2000 Swansea Corporation $3\frac{1}{2}$ per cent Stock.
£7386 12*s*. 9*d*. British Transport 3 per cent Guaranteed Stock, 1978/88.
£496 Consolidated 4 per cent Stock, 1957.
£1035 Agricultural Mortgage Corporation, Ltd., $4\frac{1}{2}$ per cent Debenture Stock, 1961–91.
£1000 Hull Corporation $4\frac{1}{2}$ per cent Redeemable Stock, 1952–72.
£700 Birmingham Corporation 3 per cent Stock, 1947.
£2280 5*s*. 3*d*. War Loan $3\frac{1}{2}$ per cent Inscribed Stock.
£1156 1*s*. 5*d*. Metropolitan Water 3 per cent "B" Stock.
£500 National Defence Loan, 1954–58, 3 per cent Registered Stock.
£500 Savings Bonds $2\frac{1}{2}$ per cent, 1964/67.
£2118 3*s*. 5*d*. Savings Bonds 3 per cent, 1960/1970 (Holding "A").
£695 16*s*. 0*d*. Conversion Loan $3\frac{1}{2}$ per cent, 1961.
£2239 13*s*. 8*d*. Treasury $2\frac{1}{2}$ per cent Stock, 1975.
£3050 13*s*. 0*d*. British Electricity 3 per cent Guaranteed Stock, 1968–73.
£3718 British Gas 3 per cent Guaranteed Stock, 1990–95.
£500 Commonwealth of Australia 3 per cent Loan, 1972–74.
£78 1*s*. 3*d*. War Loan $3\frac{1}{2}$ per cent Registered Stock.
£2400 Defence Bonds 3 per cent (5th Issue).
£3468 12*s*. 10*d*. Consolidated Stock $2\frac{1}{2}$ per cent.
£880 Defence Bonds 3 per cent (5th issue).

One Year to 1953 *December* 31 *Cr.*

	£	s.	d.	£	s.	d.	£	s.	d.	1952 £
By *Amounts received from Members* :—										
3 Partial Annual Contributions for 1951 ...	6	6	0							
3 Annual Contributions for 1951	9	9	0							
5 Partial Annual Contributions for 1952 ...	7	12	0							
27 Annual Contributions for 1952	85	1	0							
13 Admission Fees, 1952	27	6	0							
13 First Contributions, 1952	13	13	0							
722 Annual Contributions, 1953	2,274	6	0							
6 Partial Payments, 1953	9	18	0							
6 Institutional Membership Fees, 1953 ...	18	18	0							
32 Junior Members' Annual Contributions, 1953	33	12	0							
45 Admission Fees, 1953	94	10	0							
54 First Contributions, 1953	142	16	0							
				2,723	7	0				2,617
Income Tax recovered on those under Covenant				450	6	0				428
,, *Composition Fees* :—										
Reduced Fees	132	16	6							
Add Special donations from Compounders (including £26 0s. 1d. tax recovered on covenants)	57	18	1							
	190	14	7							
Less Transferred to Reserve Account ...	190	14	7							
	...	...	...							
Add Amount brought to Credit for the year	164	7	9							163
				164	7	9				
							3,338	0	9	3,208
,, Interest and Dividends received (gross)				1,103	14	10				
,, Interest received on Bank Deposit Accounts ...				139	0	3				
							1,242	15	1	1,221
,, Sales of Publications, Photographs and Miscellaneous Receipts for the year :										
Monthly Notices, Vol. 111 and earlier ...				268	12	5				59
,, ,, Vol. 112				26	9	3				59
,, ,, Vol. 113				1,189	17	3				1,119
Geophysical Supplement				314	17	10				340
Memoirs, Occasional Notes and Miscellaneous				141	15	8				56
Reprints				654	0	7				646
Palomar Slides and Prints				171	4	7				121
R.A.S. Slides and Prints				88	2	1				45
Hire of Films				49	16	0				44
British Astronomical Association				168	0	0				168
London Mathematical Society				30	0	0				30
Sundries				2	19	11				57
							3,105	15	7	2,744
							£7,686	11	5	7,173

INVESTMENTS

As at 1953 December 31

Trust Funds

£1004 Consolidated 4 per cent Stock, 1957.
£965 Agricultural Mortgage Corporation, Ltd., 4½ per cent Debenture Stock, 1961–91.
£491 10*s*. 0*d*. War Loan 3½ per cent Inscribed Stock.
£1160 16*s*. 3*d*. War Loan 3½ per cent Inscribed Stock.
£542 18*s* 2*d*. Savings Bonds 3 per cent, 1960/1970 (Holding " B ").
£1122 19*s*. 6*d*. Savings Bonds 3 per cent, 1960/1970 (Holding " C ").
£1471 4*s*. 0*d*. Savings Bonds 3 per cent, 1955/1965.
£375 Savings Bonds 3 per cent 1955/1965.
£100 Savings Bonds 3 per cent 1960/1970 (Holding " D ").
£250 War Loan 3½ per cent Stock.
£100 Defence Bonds 3 per cent (5th Issue).

Balance Sheet

	£ s. d.	£ s. d.	£ s. d.
General Fund :—			
As at 1952 December 31	29,634 12 4		
Add Rev. H. Pain Bequest	251 12 10		
		29,886 5 2	
Add Excess of Income over Expenditure, 1953 ...		461 15 11	
			30,348 1 1
Trust Funds :—			
Capital as at 1952 December 31		7,459 10 2	
Income Balances as at 1953 December 31		1,690 5 1	
Income Tax on Trust Funds, 1953 April–December not yet refunded		19 10 8	
			9,169 5 11
Arthur Stanley Eddington Commemoration Fund :—			
As at 1952 December 31	534 2 6		
Less cost of dies	125 0 0		
		409 2 6	
Income Balance at 1953 December 31		42 2 2	
			451 4 8
Repairs and Maintenance Reserve :—			
As at 1952 December 31	648 16 7		
Add Set aside 1953	300 0 0		
		948 16 7	
Less Expenditure 1953		421 8 8	
			527 7 11
Sale of Discarded Books Fund :—			
As at 1952 December 31	223 19 10		
Add Sales, 1953	401 5 0		
Interest, 1953	4 9 8		
		629 14 6	
Less Books Purchased, 1953		14 8 0	
			615 6 6
Composition Fees Reserve Fund :—			
As at 1952 December 31	2,549 1 0		
Received in 1953	132 16 6		
Special Donations	57 18 1		
		2,739 15 7	
Less 6 per cent transferred to Revenue Account ...		164 7 9	
			2,575 7 10
Staff Pension Fund :—			
As at 1952 December 31		592 6 11	
Add Interest for 1953		14 15 10	
			607 2 9
Benevolent Fund :—			
Balance at 1953 December 31			12 16 2
Amounts received in Advance :—			
Contributions :			
1954 paid in 1952	5 16 0		
1955 paid in 1952	4 4 0		
1954 paid in 1953	141 15 0		
1955 paid in 1953	9 9 0		
1956 paid in 1953	6 6 0		
1957 paid in 1953	3 3 0		
1958 paid in 1953	3 3 0		
		173 16 0	
Publications, 1954		145 16 0	
			319 12 0
Sundry Creditors for Accounts due but not presented (including provision for printing publications for 1953 and binding periodicals, not yet completed) ...			2,404 18 7
			£47,031 3 5

To the Fellows of THE ROYAL ASTRONOMICAL SOCIETY

We have examined the above Balance Sheet with the Books and Vouchers relating thereto explanations given to us.

We have verified the Securities representing the Investments and have found them to be

SUFFOLK HOUSE,
5 LAURENCE POUNTNEY HILL, LONDON, E.C. 4.
1954 February 2.

1953 *December* 31

	£	s.	d.	£	s.	d.	£	s.	d.
Investments :—									
General Fund, valued as at 1922 December 29 or subsequent cost...				30,489	17	6			
Trust Funds, valued at cost				7,548	2	2			
(Market value 1953 December 31, £37,991 18*s.* 0*d.*)							38,037	19	8
Debtors :—									
General				431	17	6			
Income Tax Recoverable :									
General Fund				48	14	3			
Trust Funds				19	10	8			
							500	2	5
Deposits at Savings Banks :—									
General Fund	£5,491	0	9						
Trust Funds (including Sale of Discarded Books Fund £584 7*s.* 7*d.*)	1,409	13	9						
				6,900	14	6			
Balance on Current Account at Bank and Cash in Hand :—									
General Fund	785	1	0						
Trust Funds (including Sale of Discarded Books Fund £30 18*s.* 11*d.*)	807	5	10						
				1,592	6	10			
							8,493	1	4
							£47,031	3	5

Note.—Contributions unpaid as at 1953 December 31, and amounting to £239 17s. 0d., have not been included in this Balance Sheet.

and certify it to be correctly drawn up therefrom and in accordance with the information and in order.

SHARP, PARSONS & CO.,
Chartered Accountants.

GIFTS AND BEQUESTS TO THE SOCIETY

Full details of the circumstances and amounts of the gifts and bequests listed below are published quinquennially, together with revenue statements concerning the Special Funds and Trust Funds. The latest statement appeared in *M.N.*, **113**, 287, 1953.

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

The John Lee Gift (1836 and 1844)
The Lawson Bequest (1856)
The Carrington Bequest (1876)
The Lambert Bequest (1877)
The McClean Bequest (1905)
The Farrar Bequest (1906)
The Parsons Gift (1922)
The Grove-Hills Bequest (1922)
The Grove-Hills Fund (1922)
The Lindemann Bequest (1931)
The Archdeacon Potter Bequest (1933 and 1951)
The Goodridge Bequest (1936)
The Herbert Spencer Bequest (1936)
The Lindley Bequest (1937)
The Stanley Williams Bequest (1939)
The E. W. Brown Bequest (1939)
The Plummer Bequest (1946)
The Carder-Davies Bequest (1948)
The M. A. Nadarov Bequest (1950)
The W. H. Owston Bequest (1951)

SPECIAL FUNDS

The Archdeacon Potter Fund (1933 and 1951)
The Victor Nadarov Fund (1950)
The Arthur Stanley Eddington Commemoration Fund (1948)
Benevolent Fund (1950)

TRUST FUNDS

The Lee and Janson Fund (1834 and 1879)
The Turnor Fund and the Horrocks Memorial Fund (1853 and 1876)
The Hannah Jackson (*née* Gwilt) Fund (1861)
The Harry Watson Memorial Fund (1923)
The George Darwin Lectureship Fund (1926)
The A. G. Stillhamer Trust (1937)
The E. W. Brown Trust (1939)
The Plummer Bequest (1946)

BEQUEST RECEIVED DURING 1953

The Rev. Harold Pain Bequest (1953): The Rev. Harold Pain, who died 1951 September 2, bequeathed to the Society the sum of £250; he expressed a wish, but without creating any trust, that the legacy would be used for the purposes of solar research.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE PRESENTED GIFTS (OTHER THAN BY EXCHANGE) TO THE LIBRARY DURING THE YEAR 1953.

Academy of Sciences, U.S.S.R.
Armagh Observatory
Association Française d'Observateurs d'Etoiles Variables
Association of Special Libraries and Information Bureaux
Astronomical Society of South Africa
Astronomical Society of Tasmania
Astronomische Gesellschaft
Astronomisch-Meteorologisch Anstalt der Universität Basel-Binningen
British Astronomical Association, N.S.W. Branch
British Interplanetary Society
British Society for the History of Science
Carnegie Institution of Washington
Centre National de la Recherche Scientifique
Deutsche Akademie der Naturforscher (Leopoldina) zu Halle
Eyre and Spottiswoode Limited
Geophysical Institute of the Faculty of Science, University of Zagreb
Geophysical Society of Finland
Goethe Link Observatory
Victor Gollancz Limited
Griffith Observatory, Los Angeles
Institut Adrien Guébhard-Séverine, Neuchâtel
Imperial Chemical Industries Limited
International Astronomical Union
International Union of Geodesy and Geophysics
Jeremiah Horrocks Observatory, Preston
" La Scuola " Editrice
Librairie Armand Colin
Maria Mitchell Association
National Oceanographic Council
National Research Council of Canada
The Editors of *The Observatory*
Observatoire du Houga
Oporto, Faculdade de Sciências
Perkin-Elmer Corporation
The Editors of *Říše Hvězd*
Royal Alfred Observatory, Mauritius
Rutherfurd Observatory of Columbia University
The Editors of *Scientific American*
Service de Prévision Ionosphérique Militaire
Sociedad Astronomico de Mexico
Union Radio Scientifique Internationale
United States Army Map Service
The Editors of *Vega*
Vieweg und Sohn
World Calendar Association Inc.

Professor C. W. Allen
Dr A. Armitage
Dr B. J. Bok
Professor S. Chapman
Professor T. G. Cowling
Rev. Dr M. Davidson
Professor A. T. Doodson
Mr R. Esnault-Pelterie
Dr D. S. Evans
Mr R. S. Garton
Mr L. F. Gilberg
Mr E. Guyot
Professor W. W. Heinrich
Dr H. C. van de Hulst
Dr P. Jordan
Professor M. Kamienski
Professor M. Minnaert
Professor F. A. Paneth
Mr D. H. Sadler
Dr M. Schuler
Dr H. Slouka
Dr A. J. Thompson
Dr I. L. Thomsen
Dr L. Thorndike
Dr G. de Vaucouleurs
Dr R. v. d. R. Woolley

OBITUARY NOTICES

The news of the death of HENRY HOWARD HAMMOND on 1953 November 19 was received with genuine regret by all who knew him, for he was a man of great personal charm. He died without recovering consciousness following a stroke while asleep, in his 85th year. He leaves a widow, a son and two daughters.

Henry Howard Hammond was born in London on 1869 February 6, and spent all his professional life as a civil servant in the Treasury, and was awarded the honour of Member of the British Empire for special services. He was elected a Fellow of the Royal Astronomical Society in 1947, and had been a member of the British Astronomical Association since 1934, in which he had served for a period as Curator of lantern slides and as a member of the Council. In spite of his age he seldom missed a meeting at Burlington House and was an active observer. He was an excellent craftsman and made several astronomical instruments.

J. L. WHITE.

WILLIAM SNYDER EICHELBERGER was born on 1865 September 18 at Baltimore, Maryland, U.S.A., where several generations of his family had lived. His father was a successful merchant, and both parents were active in church work and leaders in organizations furthering the cause of temperance and prohibition. William was educated at Baltimore College 1878–1883 and at Johns Hopkins University where he received the degree of Bachelor of Arts in 1886 and that of Doctor of Philosophy in Astronomy in 1891. In 1887–88 he was a fellow at the University, where it is recorded that he " continued to receive honors especially in mathematics during his undergraduate years ". He was instructor in mathematics and assistant astronomer at Wesleyan University in Connecticut 1890–96, and took up his life work in astronomy at the United States Naval Observatory and Nautical Almanac Office at Washington in 1896. As a result of a competitive examination in 1900 he was commissioned a commander in the United States Navy, in the corps of professors of mathematics, and was advanced to the rank of captain in 1920. In 1910 he became the tenth Director of the Nautical Almanac Office and held this post for a term equalled only by Newcomb, until he reached the age of compulsory retirement in 1929. For twenty years thereafter, until his health failed, he was employed in computational work in the scientific department of the Eastman Kodak Company in Rochester, New York. He died on 1951 February 3, at the age of 85, after two years or more of serious illness. He was married in 1894 to Vola McCrea, and was survived by his widow and by one of their three children.

Soon after joining the staff of the Naval Observatory, Professor Eichelberger took a responsible part in three expeditions to observe solar eclipses : to North Carolina in 1900, to Sumatra in 1901, and to Spain in 1905. But his most important contributions to astronomy, both observational and theoretical, were in the fields of fundamental meridian astronomy and the determination of the

positions and motions of the standard stars and of the Sun, Moon, planets and satellites. For some years before and after the Naval Observatory was moved to its present site in 1893 the work suffered, and it required reorganizing. Through Professor Eichelberger's guidance, inspiration and direction the meridian instruments and accessories were overhauled and vitally improved in many ways, modern clocks were provided, and the meridian work of the Observatory was conducted for the first time in a truly fundamental manner, so as to make the results of each programme independent of earlier work.

The observing programmes for the Sun, Moon and planets, and brighter stars, were carefully planned, and series of rigorous fundamental observations and reductions were commenced, which continue to the present time. Professor Eichelberger himself took an active part in the observing and in the reductions during the first of these series 1903–11, and he kept a supporting interest in this work for thirty years. Many volumes of the publications of the Observatory covering the work with which he was associated attest to the value of his interest and counsel.

The positions of the standard stars used in the national ephemerides were becoming inaccurate; with two of the new fundamental series at the Naval Observatory and similar series at the Cape for the southern stars Professor Eichelberger compiled his catalogue of 1504 standard stars (1925), which was at once adopted as standard by the International Astronomical Union (1925), and was used in the national ephemerides until 1940, when a newer standard became available. It has been used extensively as a standard of comparison for meridian work.

The deviation of the observed positions of the Moon from Brown's new tables led to more numerous observations of occultations of stars by the Moon, and this in turn created a demand for more accurate positions of the zodiacal stars. To supply this need Professor Eichelberger made a rigorous discussion of eleven series of observations of zodiacal stars, forming a basic normal position about the epoch 1907, and planned to combine this with earlier and later observations. The catalogue was not finished at his retirement, but, including later observations up to 1930, was published by his successor in 1940 as the Catalogue of 3539 Zodiacal Stars; it is now the standard for reductions of occultations.

As Director of the Nautical Almanac Office, Professor Eichelberger attended the international conference on astronomical ephemerides at Paris in 1911, when an agreement was made to exchange calculations among the various national ephemerides in order to unify the work and to prevent duplication. This exchange, effective in 1916 and still continuing, must be reckoned among the most successful examples of international cooperation in astronomy. He also took an active part in the Commission on Ephemerides at several General Assemblies of the International Astronomical Union, and served as President of that Commission at the Assembly of 1925.

Professor Eichelberger was an honest and talented scientist, a very rapid and accurate computer, and a hard worker. He was of the old school only in the sense that he used multiplication tables instead of multiplication machines, which were not then available. Following the example of his parents he was active in religious work and a strong advocate of temperance. He was for many years an influential member and officer of Foundry Methodist Church

in Washington. The writer was closely associated with him for twenty-eight years, and found him always a staunch and sympathetic friend.

Professor Eichelberger was a member of the American Association for the Advancement of Science (Vice-President 1906), the American Astronomical Society (council 1903–16), the Philosophical Society of Washington (President 1915), the Washington Academy of Sciences (Vice-President 1902), Correspondent of the Bureau des Longitudes, the Astronomische Gesellschaft, the International Astronomical Union (President Commission 4 in 1925), and was elected an Associate of the Royal Astronomical Society on 1925 June 12.

H. R. MORGAN.

EDWIN HUBBLE died suddenly on 1953 September 28. An internationally known cosmologist, he was an Associate of this Society and always keenly enjoyed his visits to England, where he and Mrs Hubble had many warm friends.

My own first meeting with Hubble occurred when he was just beginning observations on Mount Wilson. I received a vivid impression of the man that night that has remained with me over the years. He was photographing at the Newtonian focus of the 60-inch, standing while he did his guiding. His tall, vigorous figure, pipe in mouth, was clearly outlined against the sky. A brisk wind whipped his military trench coat around his body and occasionally blew sparks from his pipe into the darkness of the dome. " Seeing " that night was rated extremely poor on our Mount Wilson scale, but when Hubble came back from developing his plate in the dark room he was jubilant. " If this is a sample of poor seeing conditions," he said, " I shall always be able to get usable photographs with the Mount Wilson instruments." The confidence and enthusiasm which he showed on that night were typical of the way he approached all his problems. He was sure of himself—of what he wanted to do, and of how to do it.

It is not easy for a close associate to evaluate in a detached manner the work of Hubble and the contributions he made toward advancing the frontiers of knowledge. But no one could be intimately associated with him without having a sincere respect for his breadth of vision, his ever-active scientific curiosity, and his confident grasp of problems.

Born in Marshfield, Missouri, on 1889 November 20, Hubble was the son of John Powell and Virginia Lee James Hubble. He received his B.S. degree at the University of Chicago in 1910; was appointed Rhodes Scholar from Illinois that same year, and went into residence at Queen's College, Oxford, between 1910 and 1913, receiving his B.A. degree in Jurisprudence at Oxford in 1912. At Oxford he had won his Blue in track events, and was a heavyweight boxer, having boxed in an exhibition match with the French champion, Georges Carpentier.

In 1913, when he returned to the United States, he was admitted to the Bar in Louisville, Kentucky, and for a short time practised law successfully. He had never, however, lost his deep interest in astronomy, and at the end of a year he returned to research at the Yerkes Observatory of the University of Chicago.

It may be of interest that the title of his doctor's thesis was " Photographic Investigations of Faint Nebulae ". In it he considers the possible classification of nebular types, states that the planetaries are probably within our sidereal

system, while the great spirals apparently lie outside our system, and says, "These questions await their answers for instruments more powerful than those we possess". The thesis is almost prophetic of his career.

Dr George Ellery Hale, on a visit to Yerkes, offered him an appointment on the staff of the Mount Wilson Observatory, where the 60-inch was in operation and the 100-inch under construction. But in April, 1917, the United States entered the war. Hubble, who felt that the best way to see a war was in the Infantry, enlisted immediately as a private, although it meant sitting up all night to finish his doctor's thesis and taking the oral examination the following morning. He served with the American Expeditionary Force in France as Major in command of the Second Battalion, 343rd Infantry, 86th Division. After the Armistice, he remained for an additional year of duties in Europe. In the autumn of 1919 he returned to the United States, notified Dr Hale that he was free to accept his offer, which had remained open, and came on to Mount Wilson.

A brief summary of the work accomplished by Hubble can emphasize only the highlights. His first line of research at Mount Wilson had to do with a general study of galactic nebulae. One of his papers on this subject was "A General Study of Diffuse Galactic Nebulae", in which he set up a suggested classification system based upon fundamental differences between galactic and non-galactic nebulae. It was also shown that these types of nebulae were made luminous by the radiation of certain stars associated with them and that the nebulosity consisted of clouds of atoms, and dust, not hot enough to be self-luminous, but visible because of light from involved or neighbouring stars.

Another paper, "The Source of Luminosity in Galactic Nebulae", gave the relation of the luminosity of galactic nebulae to the magnitudes of associated stars, and showed that the gases were excited and made luminous by very blue high-temperature stars involved in or near the nebulosity.

Hubble's important research work on extragalactic nebulae began at about the time when the 100-inch Hooker telescope became available for observations in 1919, and his first outstanding results were obtained in 1923 with his discovery of a Cepheid variable star in Messier 31. This discovery was highly important and significant. It was the first sure indication that M 31 was far outside the boundaries of our own galactic system. By the end of 1924 he had found thirty-six variable stars in M 31, twelve of which were Cepheids. From these twelve Cepheids Hubble found the distance of M 31 to be of the order of 285 000 parsecs.

With the subsequent discovery of Cepheids in other spirals it became possible for Hubble to compute their distances by the same methods used for investigating the remoter regions of the galactic system. Further research showed that the relative luminosities of other stars in these systems, such as novae, irregular variables and blue giants, corresponded reasonably well with like objects in the Magellanic Clouds and the galactic system, and the theory of island universes was established beyond reasonable doubt.

This discovery was followed in rapid succession by papers showing that NGC 6822, Messier 33 and Messier 31 were stellar systems, whose brighter stars roughly corresponded in luminosity to the same type of objects in our own galactic system.

Another large and time-consuming investigation carried out by Hubble was his survey of extragalactic nebulae to very faint limits. For this investigation

he used the 100-inch and 60-inch reflectors on Mount Wilson. Plates were centred on approximately 1300 Selected Areas uniformly scattered over seventy-five per cent of the sky. From this material Hubble decided that the large-scale distribution of nebulae was approximately uniform except for effects of obscuration arising within the galactic system. The distribution was found to be isotropic, and as fainter limits were reached nebulae maintained a constant rate of increase.

Hubble was the first to set up a significant classification system for extragalactic nebulae. Still used today, it was developed from the study of photographs of several thousand nebulae, and was based primarily on the structural forms of photographic images. The characteristic feature of extra-galactic nebulae was found to be the rotational symmetry about dominating non-stellar nuclei. The mean absolute visual magnitude derived for nebulae whose distances could be determined was found to be of the order of $-15{\cdot}2$. Masses appeared to be of the order of $2{\cdot}6 \times 10^8\ M_\odot$.

Other important research results appeared in his papers on extragalactic nebulae as stellar systems, novae in nebulae, distribution of luminosity in elliptical nebulae, nebulous objects in M 31 identified as globular clusters, angular rotations of spiral nebulae, the luminosity function of nebulae, the motion of the galactic system among the nebulae and the direction of rotation in spiral nebulae.

Many of Hubble's results were fundamental in character. His classification system for the extragalactic nebulae and the important relationship which he found between red-shifts and distances were of this type. His correlation between red-shifts and distances, " Hubble's Law of the Red-Shifts ", is a good example of his ability to obtain results of importance with meagre available data.

In 1929 when the velocity–distance relationship was first established, the only observational data available were the velocities of some 46 extragalactic nebulae, 41 of them measured by V. M. Slipher at the Lowell Observatory, and distances of 24 objects which included the small and large Magellanic Clouds.

From the 24 nebulae for which he had estimated distances Hubble obtained his original solution indicating that for the observed range in distance (about 6·5 million light years) velocities increased at the rate of 500 km/sec for every million parsecs of distance. Since that time (1929) measured red-shifts for some 600 extragalactic nebulae have been obtained at Mount Wilson and Palomar. The largest observed red-shifts now approximate one-fifth the velocity of light and the nebulae are about 50 times more distant. It is remarkable, but typical of Hubble's work, that on the distance scale he used the additional new data have not greatly changed his original value of the constant, the present value being about 530 km/sec per million parsecs.

Some time before Hubble's death he had been well aware that a substantial correction to the old distance scale would eventually be necessary. The main reason for the revision was the discovery by Baade of two types of stellar populations in M 31 and the fact that Cepheids occurred in both Population I and Population II. Baade's data indicated that Cepheids of Population I are about one and one-half magnitudes brighter than the Cepheids in Population II. It now seems probable that the former calibration of the period–luminosity relation for type I Cepheids is in error by about $1\frac{1}{2}$ magnitudes. It follows then that M 31 is some two times farther away than Hubble's estimate which was

obtained from the type I Cepheids only. The revised distance now furnishes an explanation for a puzzling discrepancy previously noted by Hubble: namely, that the absolute magnitudes of the globular clusters in the M 31 system seemed to be from one to one and a half magnitudes fainter than those in the Galaxy. On the new distance scale they now correspond to the galactic globular clusters. Although Baade's determination of the distance of M 31 is now very near to the correct value, his factor of two cannot be used to obtain distances for the fainter nebulae, due to additional corrections arising from corrections to the apparent magnitude scale at the faint end. Sandage has already shown that the distance to M 81, for instance, is some three and one-half times the distance obtained by Hubble from the type I Cepheids. It is therefore still not possible to obtain the correct value of the Hubble expansion constant and consequently the distances to faint nebulae. In the meantime one can say that the methods used by Hubble at the time he obtained his original solution, and thereafter, are correct and cannot be improved on today. The information he needed is still not available. Once it is, then the final value of the expansion constant can be determined and distances to faint clusters of nebulae can be obtained if certain additional assumptions, such as the constancy of the absolute magnitudes, are made. It will be several years, however, before this can be done, as reliable magnitudes must be measured in many new clusters observed for velocity. When this is accomplished, the red-shift law can again be formulated and, in Hubble's own words,

> "... should furnish a clue as to the exact nature of the universe. It may then be possible to say whether or not the red-shifts are velocity shifts. If they are, then the nebulae in all directions are speeding away from us at velocities that increase directly with their distance, and space itself—the universe—is expanding at a rapid rate and in a remarkable manner. And finally it may be possible to describe the nature of the expansion and to determine the time at which the expansion began—that is to say, the age of the universe."

Another war, World War II, again interrupted his research. He sought to re-enter active service in the Infantry, but was prevailed upon by Army Ordnance to take the appointment of Chief of Ballistics and Director of the Supersonic Wind Tunnel Laboratory, U.S. War Department, Aberdeen Proving Ground, Maryland. For the duration of the war he and Mrs Hubble remained at Aberdeen, living in a cottage on a tiny island in Chesapeake Bay. For his work here Hubble was awarded the Medal for Merit in 1946, and continued as Consultant.

In 1946 he was again free to return to astronomy. From the beginning of the 200-inch project, he had served on the Observatory Committee responsible for planning this new instrument. He now became Chairman of the Research Committee for the Mount Wilson and Palomar Observatories. Late in the fall of 1949, the 200-inch was at last available for full-time observation, and Hubble was the first to use it for observational purposes. Only an observer can understand the joy of using a great instrument, and no one was more eager than Hubble to begin work with the 200-inch. His plans were clearly laid out, and he was happy to be at work again. At the time of his death he was preparing to go to Palomar for four nights of observing.

In addition to Hubble's long scientific bibliography, there are the Silliman Lectures at Yale, published under the title of "The Realm of the Nebulae";

and the Rhodes Memorial Lectures given at Oxford in 1936, entitled " The Observational Approach to Cosmology ". He was an Honorary Fellow of Queen's College. Among other honours, he was awarded the Barnard, the Bruce and the Franklin gold medals, and the Gold Medal of the Royal Astronomical Society. He was a Trustee of the Henry E. Huntington Library and Art Gallery of San Marino, California.

In 1924 he was married to Grace Burke, and their life together was a profound and happy partnership. English, as well as American, friends will remember the hospitable welcome which they always found in the Hubbles' beautiful home in San Marino and the good talk around an open fire. Hubble had many interests. He had always been a collector of books on the history and philosophy of science; he has given his valuable library to the Mount Wilson Observatory. He was a skilled dry-fly fisherman, in the Rocky Mountains and on the banks of the more classic Test, near Stockbridge, where he and his wife used to stay with English friends. In fact, it was remarked by a member of the Royal Astronomical Society that it was a curious phenomenon that Hubble's lectures in the British Isles always coincided with the rise of the mayfly.

Hubble was a brilliant leader in the field of astronomy—one who will be greatly missed, not only by his close colleagues but by the astronomical world in general.

M. L. HUMASON.

ARMIN OTTO LEUSCHNER, born at Detroit, Michigan, on 1868 January 16, died 1953 April 22 in his home near the Berkeley, California, campus of the University whose growth, reputation and achievement owed so much to his efforts. Professor Leuschner founded the Students' Observatory (now happily renamed the Leuschner Observatory) and later the Berkeley Astronomical Department, serving as Director of the former from 1898, and as Chairman of the latter from 1907 until his retirement in 1938.

In these years a great many students profited from the joint programme of the Berkeley Department and the Lick Observatory, and about sixty of them earned the doctorate in astronomy. They are to be found today in a score and a half of observatories and universities. They include Leuschner's colleagues at the time of his retirement, R. T. Crawford, S. Einarsson, W. F. Meyer and C. D. Shane, and such other distinguished astronomers as S. B. Nicholson, F. E. Ross, F. H. Seares, J. Stebbins and W. H. Wright.

Perhaps the characteristic that all of Leuschner's students remember best was his generous and conscientious interest in their development, both academic and personal. He assumed the responsibility of discovering early what a student's potentiality might be, to help him find the pattern that would lead him, with Leuschner's unceasing encouragement and aid, to an appropriate degree and career. He studied personalities and aided each of his students in improving his ways, either by quiet suggestion and example or by forthright discussion. He aided many a student financially, sometimes by finding him or giving him employment, often by obtaining a fellowship or scholarship for him. One of his enduring monuments will be the Lick Observatory Fellowship he and Director J. E. Keeler established about 1900, and the subsequent careers of the graduate students who held them. In spite of his thoughtful generosity to others,

Professor Leuschner was slow to accept return; I for one can remember his insistence that I abbreviate my acknowledgment to him in the publication of my thesis.

Not the least of the evidences of this generous spirit is the fact that most of the beneficiaries of the Berkeley–Lick programme have gone into astrophysical research. Professor Leuschner recognized the preponderant claim of individual bent and the greater opportunities of the astrophysical field, with the result that few of his students penetrated far into celestial mechanics, the field of his own paramount interest, or were able to appreciate fully his own discernment therein and contributions thereto. He was steadfast in his preference for his own field and in his faith that it would in time be returned to its place as a focus of major interest to astronomers.

Leuschner's method for the determination of preliminary orbits of comets and minor planets is known at least by reputation everywhere there are astronomers. An extension and simplification of Harzer's modification of the Laplacian method, it became the first successful rival of the Gaussian method. One of the most significant features of the new method was Harzer's introduction and Leuschner's simplification of the differential correction, which employs residuals in the improvement of an approximation and not merely in the testing thereof. The cumbersome series in observational quantities of the successive-approximation technique of Challis, later revived by Poincaré but not actually developed to practicality until recent years, was swept aside by a more powerful correction technique that acted to remove the residuals whether their cause was imperfection or error in the previous approximation.

Leuschner's lucid discussion of " range of solution " did much to improve the estimation of the accuracy of predictions based upon preliminary orbits. On this matter an interesting conflict of ideas between Moulton and Leuschner illuminated the differences between the ways of thought of these two mathematical astronomers. Moulton, closer to the pure mathematician interested in the convergence of series and in the abstractions of celestial mechanics, had questioned the Berkeley orbit computers' practice of carrying six or seven significant figures when the departure of the observations from a great circle was so small that only two or three figures could be expected to be accurate in the result. Leuschner, applied mathematician par excellence, with an incomparable feeling for the requirements of numerical calculation, saw clearly that it was a question not of accuracy but of consistency; it was necessary to carry the consistency of the figures to six or seven places to ensure the accuracy of two or three at the end.

Leuschner's " satellite solution " was the first essay at the determination of orbits inclusive of some perturbations, and has been most effective not only with satellites but also with minor planets passing close to the Earth. It seems probable that fewer of these would have been lost in recent years had this modification or similar adaptations of other methods been more extensively used. Leuschner's was also the first conscious attempt at complete elimination of parallax from the first approximation, though he was quick to show that the modern Gaussian methods accomplish the same end more simply by adopting a form for the first approximation that apparently began with Willard Gibbs.

The replacement of logarithms by desk calculating machines has led to the development of a number of excellent new methods that have to a considerable extent supplanted Leuschner's " Short Method " in practice. This development

he open-mindedly fostered and encouraged, indicating to his students that he would expect an ultimate combination of the good points from many sources. It may be remarked that the introduction of desk calculators has aided the simplification of formulae and of the development thereof and has perhaps reduced fatigue, but has not necessarily speeded up calculation; it is doubtful that anyone has ever exceeded Professor Crawford's record, using Leuschner's method and logarithms, of one hour and three-quarters for the determination of an orbit. Many a student of Leuschner and Crawford can contrast this record with his own first attempt. Three of us remember a visit from Leuschner one Christmas Eve, and his inspection of our 72 hours of calculations. "You are progressing nicely," he said with his kindly and somewhat enigmatical smile. "If you work hard tonight, you won't have to work on Christmas Day!"

He had remarkable ability to absorb and interpret the essential details of the calculations of others and an equally remarkable enthusiasm for and concentration on the problem. Not a few Berkeley graduates will remember watching him with fascination as he rolled a cigarette and lighted it, all the while talking about his favourite subject, his eyes brimming with enthusiasm and fixed on his listener. Then would come the absentminded shaking of the match, which miraculously would not go out and was often thrown, still lighted, into the wastebasket. Others may have witnessed only the dénouement—the "Chief" carrying his blazing wastebasket outside. Fortunately his office was on the ground level, next to an entrance.

Professor Leuschner's interest in perturbation theory probably dates back to his student contact with J. C. Watson at the University of Michigan 1886–1888. Later he was to take over the care of the 22 Watson asteroids under the terms of Watson's will and the Watson Fund of the National Academy of Sciences. For those, with the assistance of students and collaborators, he constructed general perturbation tables, preferring Hansen's method where it was applicable. For the "unruly planet", Andromache, and other members of the "Hecuba" group whose large perturbations are due to periods approximately half that of Jupiter, and for other groups, special tables were constructed on the Bohlin–von Zeipel pattern. Two *Memoirs of the National Academy of Sciences* and volume 20 of the *Publications of the Lick Observatory*, the last published jointly with Dr Sophia Levy McDonald in 1952, contain the results of these investigations. Together with the "Research Surveys of the Minor Planets", *Publ. Lick Obs.*, **5**, 19, they express Professor Leuschner's conviction that the loss of minor planets can be prevented more effectively by first-order general perturbation theories founded upon good basic elements than by empirical adjustment of the latter with the aid of later observations. The "Research Surveys" bring together all available references to source material to encourage investigators to undertake arduous general theories.

Leuschner was a penetrating scholar in a field that requires scholarship even more than pioneering experimentation and far more than extensive accumulation of publishable data. His insight and ability to trace out usable paths in the vastness of celestial mechanics have produced an effect that intangibly will live on.

A third facet to Leuschner's career, relatively unknown to astronomers elsewhere and perhaps not well known to his students and colleagues, concerns his service to the University of California. He had a wide interest, covering all fields of the University's activities, and did more than anyone else to establish

high standards on the Berkeley campus and to give it its reputation as a great university. He was Dean of the graduate school 1913–18, 1920–23, Chairman of the Board of Research 1923–25, and undertook many other posts and responsibilities that show the extent to which he had the confidence of both the faculty and the administration. He had a reputation for "good sense, objectivity, fairness, equanimity, and adroitness in dealing with people".

On the national scene Leuschner played a leading role in the formation of the American Association of Universities and thus in the general upswing of research and graduate instruction throughout the country that began with the turn of the century. He was also President of the American Association of University Professors 1923–25.

Elected a Fellow of the Royal Astronomical Society in 1927, Leuschner was made an Associate of the Society in 1938. He was a charter member of the Astronomical Society of the Pacific, serving as its president in 1908, 1936 and 1943 and receiving its Bruce gold medal in 1936. He was University of California Faculty Research Lecturer in 1915 and Halley Lecturer in 1938. He received the Watson gold medal of the National Academy of Sciences in 1916, the Rittenhouse medal in 1937, and was made Knight of the Order of the North Star (Sweden) in 1924. He was a member of the National Academy of Sciences, and executive secretary of the National Research Council in 1919. He was chairman of Commission 20 of the International Astronomical Union 1919–38 and honorary chairman thereafter. He was a member of the American Astronomical Society, the Astronomische Gesellschaft, and many other learned societies.

Ida Louise Denicke became Mrs Leuschner in 1896 and is remembered by students, colleagues and many others as a gracious hostess and kindly friend until her death in 1941. Professor Leuschner is survived by a daughter, Dr Erida Leuschner Reichert, and a son, Richard Denicke Leuschner.

SAMUEL HERRICK.

PROCEEDINGS OF OBSERVATORIES

Royal Greenwich Observatory

(*Director, Sir Harold Spencer Jones, F.R.S., Astronomer Royal*)

Meridian department.—The programme of astronomical observations with the Airy transit-circle has been restricted to the Sun, Moon and planets, together with the usual clock and azimuth stars. The following observations were obtained during the year :—

Sun	147	Other major planets	36
Moon	93	Ceres	4
Mercury	8	Juno	2
Venus	57	Vesta	16

Standard stars 2803

During the summer a series of observations was made with the Airy transit-circle of double transits of azimuth stars with concurrent measures of the azimuth of a survey beacon lamp mounted on the long-disused meridian mark obelisk at Chingford, eleven miles north of Greenwich. The lamp was supplied and maintained by the Director of the Ordnance Survey. It is hoped that an accurate value of the azimuth of this mark, in conjunction with a survey triangulation from Greenwich to the new site of the Cooke transit-circle at Herstmonceux, and a determination of the deflection of the vertical at the two stations from gravity anomalies, will lead to values of the astronomical latitude and longitude of the new site, for comparison with those obtained by the classical astronomical methods.

The modification of the micrometer microscopes of the Cooke instrument for the attachment of the circle-reading cameras is at an advanced stage. Some experiments are in progress to determine the exposure time required, and the apparatus for advancing the films and making the exposures for the set of cameras, from one central control point, is being designed in the Observatory workshop.

The investigation into the variations of the collimation error of the Cooke transit-circle was concluded. The telescope will be used in future with that relative disposition of its component parts which gives the smallest variations.

The transfer of part of the staff of the meridian department to Herstmonceux has allowed accelerated progress on the First Greenwich Catalogue of Stars for 1950·0. The determination of the proper motions of stars not in the G.C. is nearing completion and the possibility of the calculation of the proper motions of the G.C. stars contained in the catalogue by punched-card methods is being investigated. Some years ago the Greenwich places from this catalogue were sent in manuscript to Dr Morgan for incorporation, with those from the two previous Greenwich catalogues, in the recently published N30. Similar data for

the FK3 stars have been sent to Professor Kopff to assist in his proposed revision of that catalogue.

The building to house the Cooke transit-circle at Herstmonceux has been erected and electrical wiring is in progress. The transit-circle has been dismantled ; the base plates were placed in position in the new building before the walls were erected.

Time department.—During the year astronomical observations for time determination continued to be made at both Greenwich and Abinger. Until June 30 the standard instrument at Greenwich was Transit B, mounted in the Altazimuth dome. From that date Transit C was the standard instrument, mounted at first in the Courtyard dome but transferred on July 18 to the Altazimuth dome, where it remained until the end of the year. At Abinger, observations were made throughout the year with the Bamberg Broken Transit. The numbers of observations used were as follows : at Greenwich, 154 observations on 137 nights ; at Abinger, 227 observations on 132 nights. In addition 35 observations were obtained with Transit C before July 1, and 34 with Transit B after July 1.

Two more ring crystals were received from the Post Office Radio Experimental and Development Laboratories, Dollis Hill, during August, and were installed in two recently completed oscillators, B5 and B6, at Abinger. B6 appears to be satisfactory, but the frequency of B5 showed variations in correlation with the variations in atmospheric pressure ; the crystal and holder are now undergoing examination at the Post Office Laboratories. Further experimental clocks have been set going, and work is in progress on the installation, in D cellar, of operational clocks of the new design. A four-point-supported GT crystal is being supplied for incorporation in one of these standards. At Greenwich two of the GT crystals were removed from their original circuits and mounted in re-designed oscillators in another cellar.

Various minor additions and modifications have been made to the operational equipment at Greenwich and Abinger. In the Electronics Laboratory further progress has been made in the development of frequency-comparing equipment of high precision. Preparatory experiments have been carried out in the photoelectric recording of star transits. The introduction of electronic pulse dividers as the standard sources of seconds signals led to considerable changes in the operational computing technique.

From July 1 the time signals transmitted from the Royal Observatory have been adjusted as nearly as possible to a provisional uniform time system instead of to Greenwich Mean Time. This change will be a great convenience to those who check precision frequency standards against the nominal interval of 24 hours between corresponding signals on consecutive days. The Time Service Bulletin will relate the times of reception of radio time signals to the same uniform time system, but it will be possible to refer the reception times to G.M.T. by employing the figures tabulated in a Supplement to the Bulletin.

Astrometry and astrophysics department.—The Astrographic refractor has been used mainly for the photography of minor planets. During the year the following numbers of plates were secured : on Ceres 10, on Juno 2, on Vesta 14 : on other minor planets 79. Jupiter's satellites were photographed on 4 plates, and 6 plates were secured on the 1954 eclipse field and on two comparison fields respectively. In addition test plates have been secured on three fields at

declinations $+62°$, $+27°$ and $0°$ at varying hour angles to investigate the errors introduced into the places of minor planets when photographed away from the meridian. The numbers of plates of these three fields obtained during the year were 25, 41 and 24 respectively.

With the 36-inch Yapp reflector 98 exposures on 82 stars have been obtained in continuation of the programme of accumulating a collection of low-dispersion spectrograms. The output from both instruments has suffered from the extremely bad observing conditions during the last three months of the year.

Eclipse of 1954 *June* 30.—In preparation for the projected expeditions to Sweden the 7-inch 21-foot refractor has been mounted on the field equatorial mounting. This instrument has been temporarily placed in the Thompson dome for test purposes but the mounting is arranged for the latitude of the Swedish site. Owing to bad observing conditions tests have been restricted to focusing exposures and adjustment of the clock drive. It is planned to determine the Einstein displacement by photographing the eclipse field and a selected nearby field on the same plate and comparing the plates taken during the eclipse with plates of the same fields taken a few months later : the nearby field will be used to determine the differential scale and the eclipse field to determine the Einstein displacement, using the value for the differential scale already obtained. Ciné apparatus used at the 1952 eclipse will be employed with only minor modifications, at one station where the eclipse is partial and at one where it is total, on a programme of determining the Moon's place with precision.

Eclipse of 1948 *November* 1.—A paper on the general principles of the partial eclipse method has been published ; a second one on the actual work at the Mombasa eclipse is in the press; and a third paper embodying the results is nearly complete.

Solar department.—The Sun was photographed at Herstmonceux on 306 days. Up to October 31 no day is unrepresented in the combined Greenwich–Cape series. Cape negatives in duplicate have been received up to 1953 September 30.

The measurement of the combined series of photographs has been made from 1952 March 1 to 1953 May 16. Tables of the mean daily areas and mean latitudes of sunspots for each solar synodic rotation for 1948 have been published in *Monthly Notices* and the data for 1949 are in course of publication. The *Greenwich Photoheliographic Results* for 1940, 1941 and 1945 have been published.

The Sun's disk was observed in Hα on 126 days. On 49 days observations were possible for not more than 15 minutes. As in previous years, observations were directed to (1) the occurrence of flares, (2) photometer measures of normal bright flocculi and of flares, and (3) the location and measurement of line-of-sight motions shown by disk markings and limb prominences.

Only five solar flares were observed during the year. This number represents one flare per 10·3 hours of observation, and clearly indicates the present low level of chromospheric activity. These flares were all below importance 3.

The S.E.A. (sudden enhancement of atmospherics) recorder was operating throughout the year. The traces indicate the occurrence of eight flares in Greenwich daylight hours, but with the exception of one on October 14, probably none of these flares rose to importance 3 on the international scale. Two additional minor flares may also be indicated, but there is uncertainty because of the smallness of the trace impulses in question.

Twelve sets of photometric measures were made under the above heading (2), and 116 measures under heading (3). No velocity over 100 km/s was observed during the year.

All the principal optical components for the solar spectrograph installation have now been received or will be received shortly. Both prism-trains, one with three solid glass prisms and the other with three liquid prisms, have been presented, with suitable collimator lenses, to the Observatory by Mr J. Evershed, F.R.S. Two 16-inch quartz flats and one 12-inch quartz flat for the coelostat, and a $10\frac{1}{2}$-inch objective have been finished by Messrs Cox, Hargreaves and Thomson. Some improvements have been made to the coelostat-housing and underground spectrograph-room. Various tests on the temperature-control and air-flow have been carried out and most features of this aspect of the installation have been decided. Constructional work on the coelostat and secondary mirror mounting, incorporating the principal parts of a coelostat presented by Mr Evershed, has been started in the Greenwich workshops. Detailed design work on the remainder of the equipment is in hand.

Nautical Almanac Office.—The 1954 editions of the annual publications of the Office and the four-monthly parts of the *Air Almanac* for 1953 September to 1954 August have been published during the year; no changes have been made in these publications. The editions for 1955 are at various stages of publication.

Two volumes of A.P. 3270 *Sight Reduction Tables for Air Navigation* and four volumes of HD 486 *Tables of Computed Altitude and Azimuth* have been issued during the year, thus completing these two publications. In the course of the last few years the provision for astronomical navigation, both at sea and in the air, has been completely revised. These publications, which are on sale to the general public, essentially terminate this revision; it is hoped that the present provision will suffice for many years to come.

The discussion of observed occultations for 1949 and 1950 has been published in the *Astronomical Journal.* During the early part of the year six occultations were observed at Herstmonceux by the staff of the Office, but the Newbegin telescope ceased to be available for this work after April.

The Office has continued to be much occupied with the work involved in introducing the changes decided at the Rome meeting of the International Astronomical Union. During the latter part of the year much progress has been made with the calculation of the amended ephemeris of the Moon for each hour to $0^{s}\cdot001$ in R.A. and $0''\cdot01$ in Dec., for the years 1952–1959, from the values of the longitudes and latitudes at 12^{h} E.T. supplied by Dr W. J. Eckert through the U.S. Naval Observatory. These values are intended for early publication in a "Joint Supplement" to the *Nautical Almanac* and the *American Ephemeris.*

A specially designed card-controlled typewriter (almost identical with the one in use at the U.S. Naval Observatory) was installed early in the year. This machine automatically types, on a precision typewriter, results corresponding to the calculations made on punched cards ; its special features are its flexibility of types, horizontal and vertical spacings and the control exercised over the machine by punched or plugged instructions. The machine is being used for the preparation of copy for some of the Office publications in a form suitable for direct reproduction by photolithography; the first such publication will be *Apparent Places of Fundamental Stars* for 1956.

For most of the year the Office had the advantage of the presence of Dr S. Herrick and Mr C. G. Hilton of the Astronomical Department of the University of California, who spent a sabbatical year working at the Observatory. Their visit has intensified interest in the preparatory work for the next volume of Planetary Coordinates to cover the years 1960–1980 ; in particular, much work has been done in investigating the relative advantages of various methods of calculating planetary perturbations.

General.—The contract has been placed for the equatorial group of telescopes, which includes buildings and domes for three refractors and three reflectors, together with laboratories, dark-rooms, plate-standardizing room, aluminizing room, etc. The construction has been commenced; the contract date for completion is 1955 May.

Royal Observatory, Edinburgh

(*Director, Professor W. M. H. Greaves, F.R.S., Astronomer Royal for Scotland*)

Stellar spectrophotometry.—The scheduled observing programme of the early-type stars, which was started in 1938, was completed during the year. In all, 800 spectrograms have been secured of 100 stars ranging in magnitude from 1·2 to 5·7 and in spectral type from O6 to A0, the material being as homogeneous as is possible in such an extensive programme. All spectra were photographed on Ilford Astra VIII panchromatic emulsion using the 36-inch Cassegrain reflector in conjunction with the two-prism train of the attached Hilger universal spectrograph giving the respective dispersions 132, 45 and 28 A/mm at $H\alpha$, $H\beta$ and $H\gamma$. About two-thirds of the spectrograms have comparison spectra consisting of lines of neon, helium and mercury. In addition to the stellar spectrum each plate has two series of standardization spectra photographed in a multiple-slit calibration spectrograph.

Since the completion of the observing programme, the 36-inch reflector has been partially dismantled and an overhaul has been started. A number of minor faults are to be corrected and some modifications made.

With regard to the analysis of the stellar spectra, a paper by Dr E. A. Baker describing the specialized technique of measurement and reduction of the spectrograms and giving the results for stars of type O was published in 1949 (*Publications of the Royal Observatory, Edinburgh*, Vol. 1, No. 2). The final results for the stars of type B1 are almost complete, and in the light of these results some modifications and additions are to be made to the results for the stars of type O. The final results for the O and B1 stars will be published in due course. The B0 spectra are completely measured and the reductions are in progress. The measurement scheme for the B2 and B3 stars has been planned and measures are about to be started.

A paper by Dr R. Wilson, " The Ionized Helium Series originating from the Fifth Quantum Level ", has been communicated to the Society.

Solar work.—The Sun was observed on 102 days; 58 disk drawings were made in white light and 93 observations in $H\alpha$ light. The unusually low level of activity was indicated by the recording of only a single flare—of importance 1.

In continuation of the photometric work on prominences, 23 calibrated plates of the $H\alpha$, *H* and *K* lines of limb prominences were taken during the year. It is hoped that these will reveal what changes in average brightness occur between the maximum and minimum conditions of the 11-year cycle.

The recording of the integrated intensity of atmospherics on frequencies in the range 24–27 kc/s, begun in 1949, has been continued. The occurrence of a sudden enhancement of atmospherics (S.E.A.) is evidence of increased ionization in the *D* region, caused by ultra-violet light from a solar flare. Through the improved reflectivity of the *D*-layer at these times a gain of as much as 100 per cent may be recorded in the signal strength received from distant thunderstorm sources. An analysis has been made, extending over a period of four years, of the association between S.E.A.s and flares. In confirmation of earlier work (1950), an average time lag of 7 minutes has been obtained between the peak intensity of the S.E.A. and that of the flare which generates it. This is interpreted as an effect of " sluggishness " in the response of the ionosphere, whereby the electron density (N) *builds up more slowly* than the number of ultra-violet light quanta (q) incident upon the layer.

The precise timing of flares, in relation to the various types of sudden ionospheric disturbance which they generate, has been in progress here since 1948. These time-relationships promise to yield valuable information about the extra ionization in the *D* region, in regard to height and electron density, during flare disturbances. A simple theory, connecting this " relaxation time " with the electron density N and the recombination coefficient α, has been proposed by Appleton (*J.A.T.P.*, **3**, 282, 1953) and has been applied by Mitra and Jones (*J.A.T.P.*, **4**, 141, 1953) to the problem of locating the current system responsible for geomagnetic crochets.

An analysis has also been made of the association of S.E.A.s with 413 flares of Classes 1, 2 and 3. In the hours between $09^{h}\,00^{m}$ and sunset 51 per cent of Class 1 flares, 88 per cent of Class 2 flares and all Class 3 flares had associated S.E.A.s. The percentage association is higher during the middle of the day and in the afternoon than in the early morning hours. It is also higher in winter than in summer. As a means of flare detection, it is emphasized that three or four 27 kc/s recorders well distributed in longitude would provide almost complete coverage for the recording of major flares ; the method might profitably be used during the International Geophysical Year of 1957. The results of this work have been published by Dr M. A. Ellison, under the title " The Hα radiation from solar flares in relation to sudden enhancements of atmospherics on frequencies near 27 kc/s", in the *Journal of Atmospheric and Terrestrial Physics*, **4**, 226–239, 1953.

A short-wave receiver of standard communications type has been modified by Mr H. Seddon to record incoming field strengths from transmitting stations and will be used in connection with the flare research programme. It is not proposed to operate it continuously until the new sunspot cycle is under way as the information it will supply is required only to expand the data on flares already obtained from the long-wave receiver.

Further routine measurements of the wings of the *K* line have been made by Dr M. J. Smyth with a photoelectric spectrophotometer. Reduction is complete and the results are being analysed. Solar and geomagnetic activity during the year were low, and little variability in the violet wing of *K* is indicated. Experiments on compensation for seeing, on the use of the 1P22 photomultiplier in the Hα region and on oscilloscope display of line-profiles have been carried out.

Schmidt telescope.—Films of north-polar fields, taken with the 24/16-inch Schmidt telescope, have been measured with the Kipp and Zonen star actinometer for the determination of the off-axis corrections. It is clear that even at the

edges of the field of 4 degrees' diameter these corrections do not exceed 0·02 magnitude. A preliminary account of these, and other, results was contributed to the Newcastle Colloquium on the Design of Astronomical Instruments (see *The Observatory*, **73**, 182, 1953). A number of open galactic clusters have been photographed in light of two colours, and measurement of these films is now in progress.

Scintillation and photomultiplier.—A new photomultiplier, type 6685 (EMI) of greater sensitivity and signal-noise ratio has been obtained, with the intention of recording stellar scintillation at apertures down to one inch, for which previous results with the 1P21 have indicated that investigation would be worth while. The performance of the tube has been found to be slightly better than the manufacturer's claim. A new stabilized power supply with maximum output of $2{\cdot}3 \times 10^3$ volts and a highly stable vacuum tube voltmeter have been designed and constructed to operate the tube, which can now operate the Cossor Model 1049 oscillograph and a recording milliammeter simultaneously. A few results on A0 stars have indicated the linearity of the equipment.

Clocks.—Riefler 258 was cleaned at the Chronometer Repair Department of the Royal Greenwich Observatory, by kind permission of the Astronomer Royal, and was re-erected and adjusted by Mr D. W. Evans in August. Leroy 1230 and Shortt 4, which were cleaned by Mr Evans in 1952, have continued to keep good rates.

Time service receiver.—A new receiver for checking the Observatory clocks against the various standard time transmissions has been designed and is in process of construction.

Seismology.—Our thanks are due, as in former years, to Mr H. Tillotson for undertaking the reading of the Milne–Shaw seismograph records and for answering correspondence arising from them.

Visitors.—Visiting scientists during 1953 included Sir Harold Spencer Jones, Dr Suemoto, Mr A. N. Argue, Mr B. G. Tunmore and Major W. M. Lindley. We were also pleased to welcome a party from the Edinburgh Astronomical Society.

Staff.—Dr E. A. Baker, Principal Scientific Officer, retired in March 1953 after being on the staff of the Observatory for 39 years. Dr H. E. Butler has been appointed in his place.

Royal Observatory, Cape of Good Hope

(*Director, Dr R. H. Stoy, H.M. Astronomer*)

Reversible Transit Circle.—The observations for the new catalogue begun in 1951 were continued. The stars south of $-80°$ have received preferential treatment in the hope that this part of the catalogue may be completed in 1954. In all, 9174 transits were observed during 1953, including the following observations of bodies in the solar system :—

Sun	138	Jupiter	23	Vesta	37
Moon	61	Saturn	25	Juno	1
Mercury	46	Uranus	27	Pallas	3
Venus	89	Neptune	28	Ceres	3

Cape Photographic Catalogue for 1950·0.—Work on this project has proceeded steadily. The typescript of the catalogue for the $-60°$ to $-64°$ zone was completed. An analysis of the residuals of the measures was made for the zone $-64°$ to $-68°$ and the systematic corrections depending on position, magnitude and colour found and applied. All the material relating to the $-56°$ to $-60°$ zone has been returned to the Cape from Greenwich where, through the kindness of the Astronomer Royal, the plates had been measured and reduced as far as to give positions for 1950·0. A start has been made with preparing the corresponding catalogue. The precessions for 1950·0 have been computed and the derivation of proper motions has been commenced. The necessary photographs for the zones between $-80°$ and the South Pole were taken during 1953.

Parallax programme.—The observations for the main part of this programme were completed in 1951 but 215 plates intended for the determination of proper motion were obtained in 1953. 1013 plates were measured for parallax and 87 were rejected, leaving 3508 still to be measured. Parallaxes were derived for 32 stars, none of which had a parallax previously determined at the Cape.

Stellar photometry.—The greatest advance in the Cape photometric programmes during 1953 was the adoption of a definitive system of stellar magnitudes. This " 1953 S System " is defined in Cape Mimeogram No. 3 by the magnitudes and colours of 740 stars in the nine standard E regions at $-45°$. These magnitudes are based on sixteen series of photoelectric and Fabry observations made between 1945 and 1953 at Pretoria, Bloemfontein and the Cape, while their zero point is fixed by the special series of observations made at the Cape in 1952. The magnitudes given cover the interval between the second and the sixteenth magnitude, but the standard system can, as yet, only be regarded as definitive as far as the eleventh magnitude. Work aimed at extending this system to the fainter stars is being continued. Cape Mimeogram No. 2 gives the identification of the stars for which magnitudes are given in Mimeogram No. 3, while Mimeogram No. 4 gives the results of the individual series of observations from which these definitive magnitudes were derived.

Cape Mimeogram No. 1, which was also prepared in 1953, gives the magnitudes and colours of the 885 stars brighter than HR 5·0 and south of declination $+6°$. These magnitudes and colours are based on Fabry and photoelectric observations made between 1945 and 1952.

The Photometric Cameras were used to obtain 152 pairs of plates for the programmes begun in 1952 December. The first of these programmes is intended to provide photographic and photovisual magnitudes for the 9400 stars between $-64°$ and $-72°$ to be included in the Cape Photographic Catalogue for 1950·0. The second programme, which is receiving priority, aims at comparing the 9 E regions at $-45°$ with the 12 C regions and the 24 Kapteyn Selected Areas at $+15°$. 13100 images on 33 pairs of plates were measured with the Schilt Photometer for this programme during 1953. The stars being measured in the Selected Areas are those which Professor Redman and Dr Beer compared directly with the North Polar standards when the Photometric Cameras were on loan to the Cambridge Observatory.

A new " Bright Star Programme " has been drawn up. This includes all stars in the Yale *Bright Star Catalogue* between $-4°$ and $-64°$ together with a number of fainter stars from the radial velocity and parallax lists. 2800 two-colour observations were made for this programme during 1953 with the photoelectric photometer attached to the Astrographic Refractor.

This photometer was also used on 18 nights at the beginning of the year to get additional observations for tying the E regions to a number of northern clusters. Later in the year it was used on 9 nights to tie E2 and E3 to the Harvard Standard Sequence No. 1 near the Small Magellanic Cloud. 605 two-colour observations were made for these two programmes.

The Victoria Telescope was used on 44 nights to obtain 1040 photoelectric observations of stars in the E regions. On 25 of these nights a photometer belonging to the Washburn Observatory was used and on the other 19 a newly constructed photometer which uses an EMI photomultiplier cell. Sufficient ultra-violet light is transmitted by the 24-inch lens of the Victoria Refractor to make three-colour (U, B, V) photometry possible. As the Washburn photometer was fitted with the appropriate filters, the principal object of the observations made with it was to investigate the effect produced by the small amount of light to the violet of 3800 A that is included in the SPg magnitudes. With the other photometer two-colour observations of the fainter stars in the E regions were made, as suitable three-colour filters did not become available until the end of the year.

On 24 nights between February and May the Victoria Telescope was placed at the disposal of Dr Code and Mr Houck of the Washburn Observatory for photoelectric observations in connection with their attempt to locate the spiral arms of the southern part of the Milky Way. Mr Houck made a three-colour survey of selected O and B type stars for which classification spectra were being obtained at the Radcliffe Observatory by Dr Code. Mr Houck also made three-colour observations of 80 stars in the galactic clusters NGC 3532 and NGC 6231 of the short-period variable EH Librae and of several O and B type stars in the Large Magellanic Cloud.

During November Mr Beggs of the Cambridge University Observatory fitted a pulse-counting photoelectric polarimeter to the Victoria Telescope. After a number of minor modifications had been made he found that he could easily detect a polarization of 1 per cent in an $8^{m}\cdot 5$ star using an integration time of 40 seconds. During December he made 75 observations of stellar polarization. The pulse-counting equipment was also used on one night in conjunction with the Cape EMI photoelectric photometer to make observations of a magnitude sequence in the Small Magellanic Cloud.

After a definitive magnitude system had been adopted, a start was made with the final reductions of the photometric durchmusterung of the brighter stars in the E regions, the measures for which were made in 1948. 756 supplementary Schilt Photometer measures were made in 1953 mainly of stars which were too bright to be measured on the 15-minute exposure plates, but not quite bright enough to be included in the Fabry programme.

Some progress was also made with the durchmusterung of faint stars in the E regions. 7700 images were measured with the Schilt Photometer and the results for the regions E3–E8 were coordinated. 22 extra plates (10 photographic and 12 photovisual) of E9, E1 and E2 were obtained with the Victoria Refractors but have not yet been measured.

Variable stars.—During 1953 Mr R. P. de Kock made 6935 observations of 180 long-period variable stars using the Six-Inch Telescope. He has also kept a watch on two "flare" stars 013418 UV Ceti and 203501 AE Aquarii. 833 two-colour photoelectric observations were made of Epsilon Coronae Australis, BL Telescopii and AL Velorum which were also being observed spectroscopically

at the Radcliffe Observatory. Epsilon Coronae Australis is a W Ursae Majoris type star. BL Telescopii appears to be a supergiant eclipsing system with an F8 primary star being partially eclipsed by an M-type secondary in a period of 778·0 days. The 1953 observations covered a decline to minimum and as much of the subsequent recovery as was possible before the star was lost in the evening twilight.

Occultations.—110 observations of 45 phenomena were made with various telescopes at the Observatory. 18 of these observations were made photoelectrically, the remainder visually. The reappearance of Antares at the dark limb on March 8 was observed photoelectrically both at Pretoria and the Cape. The observation at Pretoria, which was made possible through the kind cooperation of the Electronics Sub-Division of the National Physical Laboratory of the C.S.I.R., successfully recorded the reappearance of Antares B. At the Cape records of the reappearance of both Antares A and B were obtained.

Photoheliograph.—The Sun was photographed on 339 days, two photographs being taken each day. Visual observations to determine the orientation were made weekly and photographic observations for the same purpose every two weeks. The plates have been forwarded to Herstmonceux for measurement at the Royal Greenwich Observatory where similar plates are taken.

Radcliffe section.—Of the 122 nights assigned for the use of the Cape during 1953, 53 were completely clear, 23 more than half clear, 22 less than half clear and 24 completely cloudy. 78 nights were used for spectroscopic observations, 13 nights for direct photography, 5 nights for photoelectric photometry and 2 nights in connection with the photoelectric observation of an occultation of Antares.

The total number of stars included in the present radial velocity programme is 450, of which 24 are standard stars. The majority of stars have been selected on account of large parallax or because they are within the area of $6° \times 6°$ surrounding each of the Kapteyn Selected Areas Nos. 140–206, and their annual proper motion as given in the G.C. exceeds $0''·1$. 717 spectra were obtained for this programme during 1953. 826 spectra were measured and reduced. This includes a number of duplicate measures of difficult spectra and of spectra of the standard stars that are being observed at the request of Commission 30 of the International Astronomical Union. 93 stars, for which four or more spectra had been obtained, were removed from the observing list. 30 of these 93 stars appear in the new Mount Wilson "General Catalogue of Stellar Radial Velocities" compiled by R. E. Wilson, but the catalogue radial velocities are marked as being of low precision for 6 of these 30 stars. For the remaining 24 stars the agreement between the radial velocities given in the Catalogue and those determined by the Cape is very good. The systematic difference, in the sense Cape *minus* Catalogue, is only $-0·3 \pm 0·3$ km/sec.

During 1953 a spectral classification programme was begun. This seeks to determine spectral types from small-dispersion slit spectra using the methods so successfully developed by Morgan and his collaborators at the Yerkes Observatory. The initial working list includes the 139 MK standard stars which are accessible from Pretoria and all stars brighter than the tenth magnitude on the radial velocity programme and in the E region sequences of standard magnitudes. Later it is hoped to include many of the bright southern stars whose magnitudes and colours are being measured at the Cape. 223 spectra have

been obtained for this programme, the standard stars receiving priority. All the spectra have been classified once. Later an entirely independent classification will be made.

78 direct photographs were taken at the Newtonian focus. Of these 41 were for the programme which aims to provide a photographic durchmusterung for the central portions of the E regions and the Kapteyn Selected Areas Nos. 140–206. The other 37 were long-exposure photographs of extragalactic nebulae.

Publication of observations.—The *First Cape Catalogue for 1950·0* and *Cape Annals*, Volume XV (Details of parallax determinations) were distributed. Cape Mimeograms Nos. 1–4 were prepared and distributed to those known to be interested. Further copies are available for distribution on request.

Armagh Observatory

(*Director, Dr E. M. Lindsay*)

Progress has been made with the measurement of some of the material, mainly ADH plates, obtained last year in South Africa. A Catalogue of emission objects in the Small Magellanic Cloud for which magnitudes and colours have been obtained has been completed and Part I is ready for the press. Some further observations are needed for the eclipsing binary programme undertaken in conjunction with Dr Cillié, and it is expected that these can be obtained in the coming year. The reduction of the Coal Sack plates has been delayed until a microphotometer is available. Funds have now been provided for a dual-purpose photometer for the measurement of magnitudes and the analysis of spectra. Meteorological observations and reductions were carried out by Miss Sheelagh Grew.

Dr Öpik has been engaged on the theory of meteor ionization and radiation and on the analysis of the distribution of the geocentric motions of meteors. His preliminary experiments with the vibrating camera for recording meteor velocities reveal all the peculiarities of the method and show that a vibrating camera can be expected to give twice as many meteors as a non-vibrating one of equal optical performance.

Contribution No. 9, *Leaflets* Nos. 15–19 and *Harvard Reprint* No. 370 have been distributed. *Contribution* No. 10 and a *Harvard Reprint* on V525 Sagittarii (*M.N.*, **113**, No. 4) have been published and will be distributed shortly. *Leaflets* Nos. 16–22 have been published. " Convective Transfer in the Problem of Climate " by E. J. Öpik has been published as *Geophysical Bulletin* No. 8 (1953) of the Dublin Institute for Advanced Studies.

Papers in press at the end of the year are : " The Dimensions of Omega Centauri " by E. M. Lindsay (" Vistas of Astronomy ") to be distributed as *Armagh Obs. Contr.* No. 14; " Disturbances in Dwarf Stars caused by Nuclear Reactions and Gas Diffusion " by E. J. Öpik (*Mem. in 8° de la Soc. Roy. des Sc. de Liège*) and " The Chemical Composition of White Dwarfs " by E. J. Öpik (*Mem. in 8° Liège*) which will be combined into *Armagh Obs. Contr.* No. 12/13.

The manuscripts of the following papers have been completed : " Meteor Ionization and Radiation. I. The Luminous Efficiency of Excited States " by E. J. Öpik ; " Interplanetary Gas " by E. J. Öpik; " Emission Objects in the

Small Magellanic Cloud. I. Objects showing the Nebular Lines" by E. M. Lindsay. Dr Öpik has continued to edit *The Irish Astronomical Journal* published by the Irish Astronomical Society.

Visits by the public continued to be numerous. Visiting scientists included Dr R. L. Smith-Rose, the Rev. Fr O'Connell, Professor L. W. Pollak, the Rev. Dr Martin Davidson, Dr M. A. Ellison, Dr Bart J. Bok and the Rev. Fr Ingram.

Lectures in the Department of Astronomy, Queen's University, Belfast, were given by Dr Armstrong, who resigned from the staff in October to become a Lecturer in the Physics Department. Owing to the increasing commitments at the Observatory the Director resigned as Lecturer and Head of the Department of Astronomy.

Dr Öpik attended the Liège Symposium on Nuclear Processes in Celestial Bodies and presented two papers. A grant towards travelling expenses was made by the Royal Society. The Director attended a conference at Leiden University Observatory in connection with possible future developments at the Boyden Station.

The Observatories, Cambridge University

(*Director, Professor R. O. Redman, F.R.S.*)

Reconstruction and re-equipment.—The spectrograph in the new solar tunnel has been completed and put into use, after exhaustive tests by Dr von Klüber and Dr Suemoto. For the time being it uses an excellent grating kindly lent by the Mount Wilson Observatory, primarily for the 1954 eclipse. Thanks to the kindness of Drs Bowen and Babcock this will shortly be replaced by a larger grating, also from Mount Wilson.

The Huggins 15-in. refractor was scrapped in July, the lens and a few other useful parts being kept. The new 17/24 in. Schmidt telescope by Grubb, Parsons and Co. was erected in the Huggins dome during the autumn and installation is now complete. Adjustments and tests are making satisfactory progress, good photographs have been taken, and it is hoped that the instrument will be in regular operation in the spring.

Grubb, Parsons and Co. are continuing work on the new 36-in. reflector, which they estimate should be delivered in the autumn of 1954.

Solar research.—In the new solar tunnel Drs von Klüber and Suemoto have used a Fabry–Perot interferometer for the measurement of profiles of well-isolated faint Fraunhofer lines, $\lambda\lambda$ 6200–6400 A, from centre to limb of the solar disk. The interferometer gives a resolving power of about one million. The Observatories are indebted to Dr A. H. Jarrett for the high-efficiency multi-layer reflection coatings of the interferometer plates. Dr von Klüber has carried out preparatory work for further investigation of magnetic fields on the Sun, using an interferometer combined with a double-image polarization arrangement. He has also prepared a general report on methods for measuring magnetic fields on the Sun.

In view of the barrier to greater and more detailed knowledge of the structure of the photosphere which is presented by scintillation due to the terrestrial atmosphere, Drs Blackwell and Dewhirst have designed and constructed a solar camera of 6 in. aperture and 40 ft. focal length, weighing approximately 100 lb. with power supplies included, which is intended to be carried by a balloon to a

height of about 60 000 ft. The apparatus should take photographs with approximately the theoretical resolution of a 6-in. telescope, in what may be hoped to be virtually perfect seeing. Novel and troublesome technical problems are involved, but many of these have already been solved and there is good promise that the remainder can be surmounted successfully. The main framework of welded aluminium tube was specially designed by Dr B. G. Neal and Mr K. Eickoff of the University Engineering Laboratory and constructed in the Laboratory Workshop. Tests and adjustments of the apparatus are continuing.

The photographs of the chromospheric spectrum obtained at the 1952 total eclipse have been investigated further by Professor Redman. The widths of narrow lines agree closely with those measured at the 1940 eclipse and the widths in yellow and ultra-violet regions respectively are consistent with the view that the line structure is determined primarily by Doppler broadening. The horizontal component of turbulence in the low chromosphere gives an average velocity about $\pm 1{\cdot}5$ km/sec. The interpretation of wider lines is more difficult and work is still in progress on the question of allowing for self-absorption, and in the case of hydrogen for Stark effect also. A difficulty with regard to the assignment of chromospheric heights to the spectra has been met by comparing line intensities with results obtained from slitless spectrograms by the Utrecht observers, Dr J. Houtgast and Mr C. Zwaan, whose cooperation has been much appreciated. Work is also in progress on the chromospheric CN bands as shown in these spectrograms, primarily to measure the rotational temperature.

With the support of the J.P.E.C. preparations have been under way for some months to observe the total solar eclipse of 1954 June 30 on the island Syd-Koster in the Skagerrak. Dr von Klüber is cooperating with Dr Jarrett in observing the corona with a Fabry–Perot interferometer and interference filter, to measure line widths and line-of-sight motions. Dr Dewhirst will use the Hills quartz spectrograph to measure the chromosphere electron temperature by Zanstra's method. A spectrograph of 24 ft. focal length, embodying the Mount Wilson grating mentioned earlier, is under construction for the purpose of continuing the examination of the kinetic temperature and turbulence of the chromosphere by line widths. In addition Dr Blackwell is planning accurate photometry of the outer corona in polarized light, the photographs to be made with the cooperation of the R.A.F. from an aircraft flying at about 30 000 ft. The 8-lens camera for this work is approaching completion.

Other solar work has included the construction by Mr B. G. Tunmore of an apparatus for measuring polarization of Hα light from prominences, and an overhaul and reconstruction by Mr Argue of parts of the infra-red solar spectrometer. Dr M. J. Smyth has submitted a paper to the Society on a search by spectrographic means for evidence of the ejection of particles from the Sun.

Stellar photometry.—A paper has been submitted to the Society describing the results of measurement by both photoelectric and photographic methods of pg and pv magnitudes of 7^{m}–$10^{\mathrm{m}}{\cdot}5$ stars in the $+15^{\circ}$ Selected Areas. The photoelectric measurement of pg and pv magnitudes of dwarf stars within 20 parsecs of the Sun was terminated when the Huggins telescope was dismantled in July. Mr Yates is now preparing the results for publication. He has also constructed a small spectrograph to measure quasi-monochromatic magnitudes (band width about 200 A) in the NPS, using a pulse-counting photometer on the 3-ft. reflector.

Mr D. W. Beggs has constructed a new type of pulse-counting photometer to measure the polarization of star light and has taken the instrument to South Africa, where it is now in use at the Cape Observatory, by kind permission of H.M. Astronomer. It will probably also be used on the 74-in. reflector at the Radcliffe Observatory.

Optics.—Dr Linfoot has made an analytical determination of the optimum aberration balancing in aplanats and anastigmats when optical performance, including chromatism, is assessed on a basis of a r.m.s. criterion of image quality. He and Dr Fellgett have been working also on the problem of assessment of optical images from another point of view, related to the information content of the image as well as its similarity with the object, which takes systematic account of the combined effects of aberrations, photographic plate grain and bad seeing.

A meeting of the Optical Group of the Physical Society was held in the Observatories on June 26 and 27.

Other investigations.—Dr P. B. Fellgett has commenced construction of a multi-channel infra-red spectrometer under a grant from the Paul Instrument Fund Committee of the Royal Society. This instrument is intended to overcome the waste of light in an ordinary scanning spectrometer, by modulating the elements of the spectrum in such a way that they may act on a single detector simultaneously and yet be separated at the output of the detector. The principal mechanical parts and some of the electronic equipment have been completed.

Dr J. N. Hodgson has completed the measurement of the polarization and reflection properties of certain thin metallic films in the infra-red. The original aim of this work was to find reflecting surfaces suitable for an infra-red Fabry–Perot interferometer. The best choice now appears to be multi-layer films of germanium, or possibly tellurium, with a substance of low refractive index such as cryolite.

Dr Beer has continued work on the spectrum of the peculiar eclipsing binary W Serpentis, with the aid of spectrograms kindly lent by the McDonald Observatory. He is also making a survey of the spectral characteristics and peculiarities of all known spectroscopic binaries.

Mr Argue has examined a number of methods which might lead to an increase of response of certain photographic emulsions when used with exposures of the order of half an hour. The only significant improvements of speed were obtained by hypersensitizing with a pre-exposure, or by refrigeration to -80 deg. C.

Some final details in the reconstruction of the recording microphotometer have been attended to. Dr Fellgett and Mr Yates have devised an arrangement whereby the output can be fed also through a set of diodes, converting the photographic density into a light intensity, which appears on a second pen recorder. This device has proved rapid and convenient, but is not yet quite accurate enough for general use.

Personal.—Mr. L. J. Stanley, head of the workshop staff, resigned on September 30 after 47 years of service; he joined what was then the Astrophysical Department of the Observatory under Professor Newall in 1906.

Mr A. N. Argue was appointed Junior Observer in February.

The Observatory Club held twelve colloquia during the year. The speakers included Professor C. W. Allen, Professor H. H. Plaskett and Professor W. M. H. Greaves.

Cavendish Laboratory

(*Director, Professor N. F. Mott*)

1. *Solar*

1 (*a*) *Routine observations.*—Regular observations have been maintained of the intensity and polarization of the radio emission from the Sun on wave-lengths of 1·7 and 3·7 m. In addition observations of the intensity have been started on 7·9 m. A further series of observations with interferometers of variable aperture has been made to determine the distribution of radio " brightness " across the solar disk at wave-lengths of 1·4 and 7·9 m. Marked variations in the extent of the corona, as observed by the intensity of the 1·4 m emission, were found to be related to the variations of the intensity of the coronal green line (**1**); since the radio emission will be determined mainly by the variations of electron density, these results therefore support the conclusions of von Klüber (**2**) that there is a connection between the extent of the white corona and the intensity of the coronal emission lines.

1 (*b*) *The structure of the outer corona.*—Following earlier work on the occultation of a radio star by the solar corona (**3, 4**), a more extended series of observations was made during 1953 June when the Crab Nebula passed near the Sun's limb.

The primary object of the new observations was to determine whether the reduction of apparent intensity of the radio star observed during the two previous years was due to absorption in the outer corona or to an increase in the apparent size of the source due to scattering by irregularities of electron density in the outer corona; an increase in size would cause a decrease of apparent intensity since interferometers of high resolving power were used to discriminate against the solar radiation. It was also hoped to observe the effect over a wider range of radial distances.

Observations were made on wave-lengths of 3·7 and 7·9 m, and in each case two separate interferometers of different resolving power were used; any absorption effects would affect both systems equally, whilst a scattering mechanism would produce a more marked effect on the system of greater resolving power. The results obtained showed conclusively that the effect is due to scattering, and the four series of observations are in excellent agreement with a derived model of the scattering extending over the range 5–20 $R_\odot$ (**5**).

It is not possible to deduce the precise dimensions of the irregularities, but the variation from the mean electron density at 5 $R_\odot$ must be in the range 100–10^5 cm^{-3} and with structure sizes of 10–10^5 km. The origin of the irregularities presents great theoretical difficulties, since even the largest permissible structure size is small compared with the mean free path.

The extrapolation of the observed scattering effect to small radial distances suggests that earlier analyses of the radio emission from the solar corona may require modification. A previous analysis (**6**) based on the observations of brightness distribution at wave-lengths of 1·4, 3·7 and 7·9 m led to a coronal model in which the electron density was $N = 1{\cdot}6 \times 10^8 R^{-5}$ cm^{-3} and the electron temperature was $T = 2 \times 10^6 R^{-3}$ deg. K. A fuller analysis to include the effects of scattering is not yet complete, but suggests that the effect will be most serious at the shorter wave-lengths, and may not affect the longer wave-lengths significantly.

2. *Observations of radio stars*

2 (*a*) *The new radio telescope.*—Regular observations with the new radio telescope (**7**) were started in 1953 March. The instrument consists of four aerials arranged at the corners of a rectangle to produce interference patterns in both coordinates, so that good positional accuracy is available in both R.A. and Dec. Each aerial is a cylindrical parabola approximately 100 m × 12 m and rotation about the long (east–west) axis permits coverage of the entire sky visible at the latitude of Cambridge.

The initial programme of the instrument has been a survey of radio stars at a wave-length of 3·7 m. The observational work for the survey is now practically complete, and the analysis of the records is proceeding. At the present time the analysis for a strip between declinations $+30^\circ$ and $+40^\circ$ has been completed, and has revealed about 160 sources, only 12 of which had been located in previous surveys.

Since the possibility of identifying radio sources with optical objects has been shown to depend very critically on the accuracy of the radio positions, great attention has been paid in this survey to factors affecting the absolute accuracy; a new system of high-speed film recording has been adopted which operates automatically on sources having an intensity greater than about 5×10^{-25} watts m^{-2} $(c/s)^{-1}$, for which the normal paper records provide inadequate reading accuracy.

2 (*b*) *Observations of individual sources.*—In addition to the general survey of radio stars a number of detailed observations have been made, both with the new radio telescope and with other systems. Some of the results are given below :—

(i) *Radio emission from IC* 443

An extended radio source in the constellation of Gemini has been identified with the gaseous loop IC 443 (**8**). Observations of the radial distribution of brightness have been made at wave-lengths of 3·7 and 7·9 m and these show good agreement with the extent of the optical object as revealed by the Mt Palomar 48-inch Schmidt survey.

(ii) *The radio emission from the Perseus cluster*

Observations with the new radio telescope have shown that about 75 per cent of the radio emission from the Perseus cluster originates in a source of small angular diameter (**9**). The remainder is in agreement with the intensity derived on the assumption that the average emission from each of the nebulae is comparable with that from nearby nebulae. Accurate observations of the position of the localized source have provided strong confirmation for its identification with NGC 1275, which, as proposed by Baade and Minkowski (**10**), thus appears to be the second definite example of intense radio emission from two galaxies in collision.

(iii) *The distribution of radio " brightness " across the Crab Nebula*

Observations with interferometers of variable aperture at a wave-length of 1·4 m have enabled the distribution of " brightness " across the Crab Nebula to be derived (**11**). The results are in agreement with those obtained by Mills (**12**) at a wave-length of 3 m, but provide more detailed information on the position and symmetry of the source than the latter observations.

3. *The general radiation*

Two series of observations have been made of the general radiation. In one of them a survey of the total radiation between declinations -30° and $+80^\circ$ has

been made at a wave-length of 3·7 m, using one of the four elements of the new radio telescope. The results of this survey have not yet been fully reduced. In the second an interferometer of variable spacing was used in the manner previously described (13) to obtain further information on the intense source of radiation observable along the galactic equator.

4. *Investigations of the ionosphere*

4 (*a*) *Scintillation of radio stars.*—Observations have been continued of the occurrence of the phenomena together with some measurements, with spaced receivers, to determine the lateral motion of the irregularities.

Plans have also been made for a large-scale experiment to determine the occurrence and magnitude of the ionospheric irregularities at widely separated observing sites; such observations might give important information on whether the irregularities arise from some internal mechanism, or whether they are due to the incidence of corpuscular streams from outside the Earth's atmosphere. At the present time observers at the following centres are cooperating: the Department of Terrestrial Magnetism, Washington; the Physics Department of the University College of the Gold Coast; the Observatory of the University of Helsinki.

4 (*b*) *The total ionization of the ionosphere.*—In making accurate observations of radio stars it is necessary to correct for the effects of ionospheric refraction; the data provided by pulse reflection methods are inadequate since they relate only to the ionization density below the level of maximum ionization. Observations are in progress to measure the effect by accurate determination, as a function of the zenith angle, of the apparent position of an intense radio star.

References

(1) O'Brien, P. A., *The Observatory*, **73**, 106, 1953.
(2) von Klüber, H., *The Observatory*, **72**, 207, 1952.
(3) Machin, K. E. and Smith, F. G., *Nature*, **168**, 599, 1951.
(4) Machin, K. E. and Smith, F. G., *Nature*, **170**, 319, 1952.
(5) Hewish, A., in preparation.
(6) O'Brien, P. A. and Bell, C. J., *Nature*, **173**, 219, 1954.
(7) Ryle, M. and Hewish, A., in preparation.
(8) Baldwin, J. E. and Dewhirst, D. W., *Nature*, **173**, 164, 1954.
(9) Baldwin, J. E. and Elsmore, B., *Nature*, **173**, 818, 1954.
(10) Baade, W. and Minkowski, R., *Ap. J.*, **119**, 215, 1954.
(11) Baldwin, J. E., *The Observatory*, **74**, 120, 1954.
(12) Mills, B. Y., *Aust. J. Sci. Res.* A, **6**, 452, 1953.
(13) Scheuer, P. A. G. and Ryle, M., *M.N.*, **113**, 3, 1953.

University Observatory, Glasgow

(*Director, Professor W. M. Smart*)

Dr Tannahill has continued his investigations on the proper motions of stars in the Boss *General Catalogue*. Preliminary results based on the motions of 8751 A-type stars give a solar motion of 0·973 (in terms of the theoretical unit of drift-velocity) in the direction of an apex at right ascension 264°·8 and declination +31°·5; the ratio of the numbers of stars in the drifts is 1·538. The vertex of star-streaming is at galactic longitude 356°·5, galactic latitude −0°·7.

Mr M. W. Ovenden, who joined the staff at the beginning of the year, has continued his reductions of photoelectric observations of eclipsing binaries obtained at the Cambridge Observatories.

Mr A. E. Roy has completed an investigation of main-sequence stellar models using Kramers' opacity and electron-scattering opacity laws, with generation of energy on the carbon–nitrogen cycle. He presented a paper, "A Composite Electron-Scattering Opacity Stellar Model", at the Symposium on "Nuclear Processes in Celestial Bodies" held at the Institut d'Astrophysique, Université de Liège, in 1953 September. Since then Mr Ovenden and Mr Roy have been studying the frequency of occurrence of commensurabilities in the mean motions of planets and satellites in the Solar System. This work has arisen from a paper published by Mr Roy, "Miss Blagg's Formula", *J.B.A.A.*, **63**, 212, 1953.

Mr D. G. Ewart has continued his investigations on the proper motions of the Second Cape Catalogue (1939). Preliminary results from 19839 stars of spectral types B8 and later (including unclassified stars) give the ratio of the axes of the velocity ellipsoid to be 0·596 with the vertex in galactic longitude 340°·3, galactic latitude $-0°{\cdot}9$. The elements derived for the solar motion give a speed of 0·962 (in terms of the theoretical unit) towards an apex at right ascension 271°·1 and declination $+24°{\cdot}6$. Mr Ewart has also made a determination of the constants of the velocity ellipsoid from the radial velocities of 820 faint stars measured at the Lick Observatory. The results were communicated to the Society in a paper, "The Constants of the Velocity Ellipsoid from the Radial Velocities of 820 Stars", *M.N.*, **113**, No. 5.

University of London Observatory

(Director, Professor C. W. Allen)

Parallax.—As decided last year, observations have been restricted to those stars that show promise of being finished in 1953 or 1954. 14 stars were placed on the observing programme, of which five have been completely photographed. 118 parallax plates were obtained. Two stars have been measured and there are eight ready to measure.

Star clusters.—A photographic unit has been attached to the 18-inch visual component of the Radcliffe telescope, with the result that red and blue pairs of plates may now be photographed simultaneously. 112 photographs of clusters and fields have been obtained. Interest has been directed towards the clusters NGC 5904 (M5), NGC 7789 and Tombaugh 5. Measurements on M5 are not as extensive as the recent results from the 200-inch telescope but general agreement with the colour array has been obtained. The plates of the other clusters are not yet photometered.

Laboratory spectroscopy.—A water vortex stabilized arc source for the excitation of spectra at high temperature has been constructed in the workshop and has been operated by Foster at Imperial College. The spectrum of steam has been observed with the view to measuring oscillator strengths of atomic oxygen. Oscillator strengths are being measured also by Asaad from arc spectra of dilute copper alloys.

Use of instruments.—The Radcliffe 24/18-inch refractor has been used on 46 nights for parallax and cluster work, the Wilson 24-inch on 3 nights for direct photography, and the smaller instruments for students and visitors.

Theoretical work and analysis.—A new system for investigating the statistics of celestial objects has been developed by the Director. Sweet is investigating the effect of a magnetic field on the stability of the Sun's outer convective layer. Reddish and Sweet have computed a model sunspot atmosphere in connection with the problem of spot structure. Garstang has completed investigations on intermediate coupling line strengths for some transition arrays of O II, Ne II, S II and A II. Transition probabilities for some lines of C I were computed. Reddish has investigated the possible course of stellar evolution and has used the results to determine the masses of dwarfs and giants of population II and of variable stars.

Publications.—During 1953: C. W. Allen, "World-wide diurnal variations of the F2 region", *J. Atm. Terr. Phys.*, **4**, 53, 1953; K. R. W. Brewer, "HD 50169, a spectrum variable with emission at Hα", *Ap. J.*, **118**, 265, 1953; R. H. Garstang, "Stellar Associations", *J.B.A.A.*, **64**, 43, 1953.

Staff and students.—Mr E. W. Foster was appointed as lecturer in January, Mrs F. B. Harland as confidential secretary in June and Mr J. R. Coy as technician in July. Mr A. S. Asaad commenced post-graduate work in September. Dr P. A. Sweet, Dr R. H. Garstang, Mr C. R. Spratt and Mr T. Kiang remain on the staff, and Mr V. C. Reddish continues post-graduate work.

Since October there have been ten undergraduate students taking either regular lecture courses or practical astronomy.

New building.—The new Office building was finished and occupied in April.

Visitors.—Mr S. N. Svolopoulos visited the Observatory from May to July and measured parallax plates.

There were 403 afternoon and evening visitors during 1953.

Radar Research Establishment, Ministry of Supply, Malvern

The radio astronomy group led by Dr J. S. Hey now includes Dr L. R. O. Storey who is constructing an apparatus for observing the 1420 Mc/s hydrogen line emission. The primary intention is to study the emission from the Andromeda nebula. To obtain the required sensitivity it is proposed to integrate the signal over several hours. The greater part of the radio receiver has been completed, and an aerial with a 20 ft. diameter parabolic reflector is under construction. It is hoped to have the whole apparatus completed by autumn 1954.

J. S. Hey and V. A. Hughes have measured the intensities of the discrete sources in Cygnus and Cassiopeia at 22·6 Mc/s by means of an interferometer with aerials spaced 20 wave-lengths apart. The results indicate that the intensity continues to rise the lower the frequency, and a discussion of the spectrum is in publication. It is hoped to measure the intensities of other discrete sources and also to study the ionospheric effects which often cause severe fluctuations of intensity.

The analysis of the distribution on the Sun of the radio bursts associated with flares has continued. A note on the E.–W. asymmetry at 4 metres wave-length is in publication.

The 10 cm wave-length radiometer constructed by V. A. Hughes is being prepared for observation of the Sun. The control system for the equatorial drive of the equipment is described in *R.R.D.E. Technical Note* 106.

Acknowledgment is made to Chief Scientist, Ministry of Supply, for permission to publish this communication.

Jodrell Bank Experimental Station, University of Manchester

(*Director, Professor A. C. B. Lovell*)

The radio telescope.—The constructional work on the radio telescope proceeded satisfactorily during 1953. The 152 deep reinforced concrete piles were completed by the early summer, and the reinforced ring beam to support the railway track was finished during the autumn. The completion of the central thrust block and the underground cable tunnel to the control room enabled all the foundation work to be finished before the end of the year. The 17-ft. gauge double railway track with an outer radius of 180 ft. is now being laid, and work on the control building has also commenced. The power house extensions have been completed and the cable laid in readiness for the cranes which are expected to commence erecting the superstructure in the spring of 1954. The consulting engineers anticipate that the main erection will be completed by the autumn of 1954. The installation of the driving system and the wire mesh on the reflecting bowl will then take place. As far as can be seen at present there is every likelihood that preliminary tests of the radio telescope will be made in 1955.

Extra-galactic radio emissions.—The measurement of extra-galactic radio emissions with the 218-ft. paraboloid has been continued. The radiation from the bright spiral nebula (M81) has been measured at a frequency of 158·5 Mc/s, and the ratio of radio flux to light flux has been found to agree well with that observed for other late-type spirals (**1**).

The detection of a very weak system of irregularities in the background radiation at high galactic latitudes has been extended. The isophotes of these irregularities have been plotted over a range of about 30° in declination. A comparison of the shape of these isophotes with the distribution of extra-galactic nebulae indicates that the irregularities are associated with concentrations of extra-galactic nebulae (**2**). The radio radiation to be expected from these concentrations has been calculated from photographic surveys of the region on the assumption that all nebulae exhibit the same ratio of radio flux to light flux as that found for individual late-type spirals. There is a discrepancy between the calculated and the observed intensities of about 2 magnitudes, which suggests that the ratio is not constant for all the nebulae.

It is intended to extend the measurements to other concentrations of nebulae and in particular to attempt to detect the radiation from the Coma cluster. The equipment is at present being modified to work on a frequency of 95 Mc/s so as to allow the beam of the 218-ft. paraboloid to be swung over a larger angle on either side of the zenith.

Galactic radio emissions.—All the available radio surveys have been analysed to construct a radio model of the Galaxy (**3**). The model shows that the radiation from the Galaxy may be explained in terms of a system of localized sources which are highly concentrated in the centre of the Galaxy, and of a disk of ionized interstellar gas whose properties are consistent with visual observations. It is suggested that the sources are rare members of Baade's population II and that they may be identified with the intense sources which have been observed to lie close to the galactic plane. The model also requires the existence of a large isotropic component of radiation whose origin is probably extra-galactic. The calculations show that at low frequencies (less than 20 Mc/s) absorption in the

interstellar gas should give rise to a band of relatively low intensity in the galactic plane. It is proposed to check this prediction by measurement of the intensity distribution across the galactic plane by means of an interferometer operating at about 18 Mc/s.

Diameter of the radio stars.—The measurement of the apparent diameter of the two intense sources in Cygnus and Cassiopeia has been continued using the new type of interferometer operating at a frequency of 125 Mc/s.

It has previously been shown with this instrument that the source in Cygnus is asymmetrical, and the preliminary measurements suggested that it is elliptical in outline. More extensive measurements along the major axis of the Cygnus source show that the source is not a simple ellipse, but that it consists of at least two radiating centres. The simplest interpretation of these results indicates that the spacing between the centre of these two elements is about $1' \, 20''$ and that their individual size is about $40'' \times 30''$ (**4**).

The recent identification of the source in Cygnus with the collision of two extra-galactic nebulae, and of the source in Cassiopeia with a new type of nebulosity in the Galaxy, makes the detailed measurement of the distribution of radio intensity across these sources a matter of prime importance. The measurements with the existing interferometer will therefore be continued to obtain the maximum amount of information possible. It is proposed to construct a second interferometer which will be capable of measuring the relative phase of the interference " fringes " and thereby resolve the ambiguities in the results of the present instrument.

It is also proposed to attempt the measurement of the apparent angular diameter of the weak radio sources by means of an interferometer operating in conjunction with the 218-ft. paraboloid. A new instrument is under construction and it is hoped that it will measure the diameter of at least the 12 most intense sources in the field of view of the paraboloid.

Wind movements in the F region of the ionosphere.—Observations of the drift movements at the 400 km level of the ionosphere by the radio star scintillation method have been continued, and observations covering a period of two years have now been analysed (**11**). The results show that the movements are normally of the order of 100–300 m/sec, are generally transverse to the magnetic lines of force and often remain appreciably constant over periods of several hours. During the first half of the night the prevailing direction is towards the west, while in the latter half of the night it is usually towards the east. Investigation of the drift motion at points separated by 800 km shows that they are the same over wide areas, and some experiments made in cooperation with members of the Cavendish Laboratory, Cambridge, over a 200 km base-line confirm this. It is found that the drift speeds may be inferred directly from the scintillation rate, and also, somewhat less accurately, from the geomagnetic K index. K indices of 0–1 correspond to drift speeds of 0–50 m/sec; with increasing K indices the velocities increase proportionately until at the highest K ranges of 8–9, drift speeds of the order of 1000 m/sec are observed.

By observing the Cygnus source when it is low on the northern horizon it has been possible to estimate the F region drift speeds in the highly disturbed auroral zone. Here the average velocity is of the order of 400 m/sec., i.e. twice the average drift speed at lower latitudes.

Hydrogen line.—The receiver for the investigation of the 1420 Mc/s (21 cm) interstellar hydrogen line is now in operation. It is being used in conjunction with the refigured 30 ft. aperture paraboloid which now has an automatic tracking mechanism for azimuth and elevation control. The profile of the hydrogen line is broadened by differential galactic rotation, and the width and fine detail of the line in certain galactic longitudes are being observed. These measurements are confirming the recent Dutch results. The spiral structure of the Galaxy is revealed from a study of these profiles, and the method enables distant parts of the Galaxy to be investigated which cannot be seen optically because of obscuration.

During 1953 the receiver was modified in order to make a search for the 177 Mc/s hyperfine structure line of excited hydrogen. It has been shown that, using the 30-ft. paraboloid, no irregularity in the spectrum exceeding 1 deg. K could be detected from the Orion nebula, the galactic plane, the Sun, or the Cygnus and Cassiopeia regions of space.

Solar radio emission and magnetic recording.—The monitoring of solar radiation at 3·7 m has been continued, but with the approaching sunspot minimum very little activity has been recorded for the past twelve months.

Continuous observations of the transient variations in the east–west component of the terrestrial magnetic field have been made with a saturable core (fluxgate) magnetometer equipment since 1950 November. A *K* scale for the Jodrell Bank records has now been drawn up in accordance with the international system, and the Jodrell Bank *K*-indices are in excellent agreement with the international figures.

Aurorae.—The observation of aurorae has been implemented by an all-round looking equipment consisting of a pair of Yagi aerials mounted 20 ft. above the ground and rotating about a vertical axis once every six minutes. The beam elevation is 10°, width 20° to half power; frequency 73·5 Mc/s; peak power 10 kW. Auroral activity of sufficient intensity to be detected by the 4-metre equipment has been very limited indeed owing to the minimum in the sunspot cycle, but some very interesting echoes were obtained on the evening of 1953 October 15, the activity being detected simultaneously on both the radiant and all-round looking equipment.

Meteor survey.—The meteor survey has been continued. The radiants and rates of all the major night-time and day-time streams have again been measured. No velocity measurements were made of these streams. The Giacobinid activity on 1952 October 9, when the Earth traversed the cometary orbit six months in front of the comet, was a highlight of the year's survey, being far greater than was expected. Fortunately, the meteor stream, which is of very small cross-section, attained its peak activity just before transit and hence came within the coverage of the radiant equipment. In 1953 observations were made on a number of radio equipments, but no activity beyond the normal sporadic rate was detected at any time within 12 hours of the expected time of maximum. A condensation was detected in the Quadrantid stream in 1953 January 3, when the rate was two to three times the usual rate at maximum. The observations of the summer day-time activity in May, June and July were supplemented by the all-round looking equipment. This equipment detected unique " bursts " of short duration echoes on June 23 and 24, for which a satisfactory explanation has not yet been found, although the activity may be associated with the Pons-Winnecke Comet.

Meteor orbits.—A new apparatus for the measurement of both velocity and radiant point of individual meteors has recently been put into operation. The measurement depends on obtaining Fresnel diffraction patterns at three stations separated by about 4 km and comparing the times of appearance of the echo at the three stations. The method is applicable to both shower and sporadic meteors, and should yield several complete orbits per hour. First results were obtained on 1953 December 13, when 13 Geminid orbits were obtained. The mean elements of these orbits agree closely with those obtained photographically by Whipple and by other means. Details of the technique and results will be published shortly (**6**).

Meteor physics.—A report of the advances which have been made by radio echo techniques has been given in a review article (**7**). The theory of the scattering of radio waves from the ionized columns produced by meteors has been extended (**8**) to include the " head echo "—a discrete echo apparently originating from the instantaneous position of the meteor particle. Theories of the meteor height distribution (**9**) and of the radio echo rate have been developed in detail, the latter leading to an estimate of the total rate of meteoric ionization.

Radio echo measurements of meteor heights have been continued and the theory of the height distribution has been applied to obtain values for the atmospheric pressure and scale height in the meteor ionization region (**10**). This involves a knowledge of the mass distribution of the incident sporadic meteors, which has been obtained by interpreting the echo rate observed as a function of equipment sensitivity in the light of the theory referred to above. Mass distributions have also been obtained for several of the major meteor streams.

The constants in the meteor ionization equations have been determined with reasonable accuracy. The most important result is that the probability that an evaporated meteor atom of velocity v will produce a free electron is of order unity, and velocity independent, for $20 < v < 60$ km sec^{-1}.

Estimates of ionic recombination in meteor trails are of the same order as the theoretical value for radiative recombination, i.e. several orders of magnitude less than the value assigned to the E region of the ionosphere. This is interpreted in terms of a difference in the ionic species in the two cases. A detailed study of the radio echo duration distribution for several showers indicates the possible influence of attachment of electrons to neutral oxygen, with a coefficient of the predicted order of magnitude.

The polarization equipment (designed to study the influence on the echo characteristics of the polarization of the wave incident on the meteor trail) has been substantially modified, incorporating a new receiver and aerial system and operating on a somewhat longer wave-length (5·5 m). In addition to the study of the mechanism of reflection of radio waves from meteor trails, this experiment should be particularly suited to the determination of the distribution of meteor masses and the total incident flux in the various meteor showers. Observations made during the 1953 Geminid shower are at present being analysed.

Upper atmosphere winds.—Work on the investigation of winds at altitudes of 80–100 km, by observations of the radio echoes from meteor trails, has continued. The construction of the new high-sensitivity equipment, begun last year, has been completed, and as a result of the hundredfold increase in usable echo rate it is now possible to study the hour-by-hour variation of wind speed and direction throughout the day. The method used is to measure the phase changes during

the lifetime of a meteor echo, as a result of a bodily movement of the ionized column in a region of uniform wind. A change in range of $\lambda/8$ (one metre at a wave-length of 8 m) produces a phase shift of 80°, and is easily detectable. The coherent pulse transmitter has a peak power of 100 kW and operates at a pulse repetition frequency of 150 c/s. Preliminary observations obtained during 1953 September and October show the presence of winds with both prevailing diurnal and semi-diurnal components. The prevailing wind blows towards the east at the beginning of September, swinging round through south towards a westerly direction in October and November. The amplitude of this prevailing wind is approximately 20 m/sec. The semi-diurnal component has a velocity of 15 to 30 m/sec, the wind vector rotating in a clockwise direction. The phase of this component is such that it blows towards the north at $03^h\,40^m$ in September and $00^h\,00^m$ in October and November. The diurnal component is very small in September, but is equal in amplitude to the semi-diurnal wind in October. The wind vector again rotates in a clockwise direction, being directed towards the north at $23^h\,00^m$. These 12 hour and 24 hour periodic winds are probably caused by the diurnal and semi-diurnal pressure variations due to solar thermal and gravitational effects (5).

120 *Mc/s lunar echo equipment.*—Lunar echo signal strengths of up to 20 dB above receiver noise level have been obtained following the construction of a new aerial system. This consists of an array of 160 half-wave elements ($8° \times 20°$) and a phasing network which enables the beam elevation to be varied between 25° and 65°. The beam azimuth is fixed (due south) and the Moon can be observed at the time of transit ± 20 min over a substantial fraction of the lunar month.

A study of the fading of the lunar echoes reveals the following characteristics : (*a*) rapid irregular, deep fading (period $\sim$1 sec) which appears to be associated with the lunar libration, (*b*) a long-period ($\sim$1 hour) deep fading which is prominent after sunrise and which it is suggested is due to double refraction in the ionosphere. This will result in a rotation of the electric vector in the received wave (relative to that transmitted) which is proportional to the component of the Earth's magnetic field in the direction of propagation and to the total number of electrons contained in a cylinder of unit cross-section situated along the ray path. If this interpretation is correct, the experiment thus provides a direct measure of the rate of change in the total ionization in the ionosphere.

References

(1) R. Hanbury Brown and C. Hazard, *Nature*, **172,** 853, 1953.
(2) R. Hanbury Brown and C. Hazard, *Nature*, **172,** 997, 1953.
(3) R. Hanbury Brown and C. Hazard, *Phil. Mag.*, **44,** 939, 1953.
(4) R. C. Jennison and M. K. Das Gupta, *Nature*, **172,** 996, 1953.
(5) J. S. Greenhow, *Phil. Mag.*, **45,** 471, 1954.
(6) J. G. Davies and J. C. Gill, in preparation.
(7) T. R. Kaiser, *Phil. Mag. Suppl., Advances in Physics*, **2,** 495, 1953.
(8) I. C. Browne and T. R. Kaiser, *J. Atmos. Terr. Phys.*, **4,** 1, 1953.
(9) T. R. Kaiser, *M.N.*, **114,** 39 and 52, 1954.
(10) S. Evans, *M.N.*, **114,** 63, 1954.
(11) A. Maxwell and M. Dagg, *Phil. Mag.*, **45,** 551, 1954.

University Observatory, Oxford

(*Director, Professor H. H. Plaskett*)

New solar telescope and spectroscope.—The mirrors of the new solar telescope were installed by Grubb, Parsons in May. Preliminary tests of the telescope have revealed surprisingly few teething troubles, and the majority of these have now been cured. The grating, objective and slit for the accompanying spectroscope have now been received, and the glass for the prisms has been ordered from Schott u. Gen. The mechanical design of the spectroscope is well advanced, though a definite tender has not yet been received.

Determination of solar and laboratory wave-lengths.—Miss Adam has completed the measurement and reduction of the interferometric spectra of the Ca and Fe lines in the regions 6570A and 6490A. Because of the width of the apparatus function of the spectroscope in these regions and in order to keep light scattered by the interferometer to a minimum, the interferometer was used with spacers of 1·4 and 2·5 mm. The wave-lengths measured with the 1·4 mm spacer show a systematic difference from those with the 2·5 mm spacer. Investigation into the cause, and the future elimination, of this source of systematic error is well advanced. During June, July and August interferometric spectra were obtained for the determination of solar and laboratory wave-lengths in the 4400A region.

Motions in the solar photosphere.—Mr Kinman (*M.N.*, **113**, 613), from measures of the Evershed effect in five additional spots, has confirmed his earlier result that the motion of the penumbral material is purely radial. He has also been able to show that the time required for this moving matter to reach its maximum velocity is independent of spot size, though the maximum velocity itself varies linearly with the umbral radius.

Miss Hart has completed her determination of the equatorial solar rotation and has communicated her results to the Society. She has been able to show that differences in the rotational velocity cannot arise from errors introduced by scattering in our own atmosphere, and that consequently these differences must be inherent in the photosphere.

Solar spectrum.—Mr Sykes' method of solving the integral equation of limb-darkening has been published (*M.N.*, **113**, 198). The Radcliffe Travelling Fellow, Mr Stibbs, has communicated a paper (*M.N.*, **113**, 493) on a simplified case of non-coherent scattering in the formation of absorption lines. In connection with his determination of the profiles of the Na lines, Mr Bray has found the apparatus function of the spectroscope in the region 5900 A. Preliminary spectra for the determination of the profile of the chromospheric He line, 5876 A, have been obtained by Mr Bishop.

Stellar and other work.—Mr Stibbs has continued his work on the radial velocities of 55 southern Cepheids, the spectra of which he obtained with the Radcliffe 74-inch. He is using these velocities, and those obtained by Joy, for the northern Cepheids, to make a new determination of the zero-point of the period luminosity law. Dr Merton has communicated a paper (*M.N.*, **113**, 428), on a new method for finding star places. He is continuing his investigation on methods of orbit computation. The International Astronomical Union has published the first volume of the Potsdam–Oxford zones of the Astrographic Catalogue.

University Observatory, St Andrews

(*Director, Professor E. Finlay-Freundlich*)

Staff.—Miss B. Middlehurst is on leave of absence for one year to do research at the Astronomy Department of the Indiana University, U.S.A.

Dr R. Kurth spent eight months at the Observatory with a D.S.I.R. Grant.

Scientific research.—(*a*) During the past year Professor E. Finlay-Freundlich has been occupied with preparations for the eclipse expedition to Sweden in 1954 June. In collaboration with Potsdam Observatory it is proposed to make new measurements of light deflection with equipment used at the 1929 eclipse—but now very much improved.

(*b*) The second possibility of testing the general theory of relativity has been for years in a state of great uncertainty. The existence of a general red shift is definitely revealed by the solar spectrum as well as by the stellar spectra. However, no quantitative agreement with the theoretical prediction could be achieved. A new attempt has been made by E. Finlay-Freundlich to clear up this problem. The surprising result came to light that all observed general red shifts, including the cosmological red shift, obey a law very different from that demanded by the theory of relativity. The observed red shifts indicate the existence of a new fundamental law for the propagation of photons through a radiation field.

Miss Middlehurst and Mr T. Slebarski helped in the collection of the data necessary for this work, and also gave assistance by giving critical discussions.

Mr T. Slebarski is continuing the statistical study of B stars with respect to this new theory; other research students are following up further problems raised.

Results so far obtained were published in the following scientific journals :—

1. *Nachrichten der Akad. der Wissenschaften in Göttingen, Math.-Phys. Klasse*, No. 7, 1953.
2. *Proc. Phys. Soc.* A, **67**, 192, 1954.
3. *Phil. Mag.*, **45**, 303, 1954.

(*c*) An apparatus for an improved scheme of photographic recording has been completed and Mr A. MacAulay is conducting tests concerning the response of the device.

(*d*) During May, Dr Jarrett visited Meudon and later in the year the Observatory of Pic du Midi, to experiment with the multi-layer Fabry-Perot interferometer intended for use in the corona investigations being conducted in collaboration with Dr H. von Klüber of Cambridge at the eclipse in 1954 June. Further work entailed the selection of a suitable interference filter for this experiment.

Publication.—A. H. Jarrett—one paper in *Zeitschrift für Astrophysik*, **34**, 91, 1953 on multi-layer coatings.

(*e*) Dr R. Kurth made considerable progress in theoretical studies on the structure of finite star systems and connected problems of celestial mechanics. His results will be published in the near future.

(*f*) Dr Cisar continued his photographic survey of extra-galactic systems and possible sources of radio-frequency emission using the 18-inch Schmidt-Cassegrain telescope. In a collaboration, which has now been put on a permanent basis, with the Department of Astronomy of the University of Manchester, he has

begun, together with Mr J. Ring of Manchester, a study of the distribution of interstellar hydrogen with the aid of interference filters made by the latter.

Workshop.—Progress on the full-scale Schmidt–Cassegrain telescope continues. The U.V. Schmidt plate has been made plane parallel and optically worked on the flat side. The 18-point flotation system for the primary mirror is completed and the secondary flotation system is under construction.

Mr Abbott, under the direction of Mr W. Stewart of the Engineering Department, United College, Dundee, is designing the mounting for this instrument.

The building to house the new 38-inch Schmidt–Cassegrain telescope is under construction.

Norman Lockyer Observatory of the University College of the South West
(Director, Mr D. L. Edwards)

The main programmes of work have been continued, including the work on galactic clusters mentioned last year. A paper on the results of the latter has been communicated to the Society by Mr S. N. Svolopoulos, who was enabled to complete the work by the aid of a grant from the International Astronomical Union.

A special investigation has been made on the technique of plate standardization for colour-temperature purposes in order to eliminate or reduce possible sources of error, especially those arising from the sensitometer and from photographic sources. An adaptor has been made to give more points on the characteristic curve, and the methods of reduction have been improved. Corrections for atmospheric extinction have also been further investigated.

Further observations of anomalous polarization effects associated with sodium emission in the twilight sky have suggested the desirability of certain improvements and additions to the equipment employed in this work. Apparatus to give synchronous recordings of zenithal light intensities at 5893 A and azimuths of the rotating polaroid filter has been constructed for use during the winter.

Daily values of atmospheric ozone are received regularly through the kind cooperation of Professor G. B. S. Dobson and Sir Charles Normand, to whom grateful acknowledgments are made.

Mr S. N. Svolopoulos left the observatory at the end of April to return to Athens, prior to taking up an appointment at the Flower Observatory of the University of Pennsylvania, U.S.A.

Dunsink Observatory
(Director, Professor H. A. Brück)

Staff.—Dr H. E. Butler, Chief Assistant, has been appointed Principal Scientific Officer at the Royal Observatory, Edinburgh, as from November 1. Dr Butler, who had been at Dunsink from the time of its re-opening in 1947, will be remembered there for his invaluable and enthusiastic assistance in the rather difficult task of reconstructing the observatory.

Mr A. N. Argue has been appointed to the staff of the Cambridge Observatories as from February 1. His place as Scholar has been taken by Dr G. I. Thompson, a graduate of Queen's College, Belfast, and Imperial College, London.

Equipment.—Plans for the construction of the new 28-inch reflector have been completed, and the tube, manufactured by a Dublin firm, has been mounted in the dome of the former 15-inch reflector. The 28-inch mirror is being refigured, and auxiliary mirrors are being made by Messrs Cox, Hargreaves and Thomson Ltd.

An iris astrophotometer for the measurement of star plates has been delivered by Messrs L. C. Eichner of New Jersey, and preliminary tests of its performance have been carried out on Schmidt plates, taken with the Armagh–Dunsink–Harvard Telescope at Bloemfontein.

A stereocomparator and a plate-measuring machine have been acquired from the Oxford University Observatory.

A milling machine has been added to the equipment of the workshop.

Solar work.—The performance of the solar spectrograph has been investigated with respect to instrumental profile and intensity of scattered light, and the results are being published as part of a description of the Dunsink solar installation in "Vistas in Astronomy" (H. A. Brück and Mary T. Brück, *Dunsink Contributions* No. 9).

Dr G. I. Thompson has been engaged in taking solar spectrograms in the ultra-violet in the second and third orders of the grating. For the direct recording of intensities he is setting up a suitable attachment, similar to the corresponding Utrecht instrument, which works in conjunction with the Moll recording microphotometer of the observatory.

Stellar work.—Dr H. E. Butler has followed up his earlier work on an indirect method of star counting, based on photoelectric measurement of the overall transparency of pairs of copies of star plates. The principle of the method has been described in the April number of *The Observatory* (*Dunsink Reprints* No. 6), and a more detailed account has been completed for publication in "Vistas in Astronomy" (*Dunsink Contributions* No. 8).

Measurement has started with the Eichner astrophotometer of the plates of open star clusters which had been secured in three spectral ranges with the ADH telescope in 1952.

Dominion Observatory, Ottawa

(*Director, Dr C. S. Beals*)

Positional astronomy.—Observations were continued on a list of stars comprising those in use or needed with photographic zenith tubes at Richmond, U.S.A., Greenwich and at Ottawa. Approximately 6000 observations were taken during the year. The computations up to 1953 have been completed to mean place and listed. This work has been completed by the University of Toronto Computation Centre.

Results of observations taken from 1935 to 1950 have been completed and are now being prepared for publication. This catalogue will contain 1525 stars along with corrections to the Boss G.C. and FK3.

Serious consideration is being given to building a "Mirror Transit" as proposed by Dr Atkinson (*M.N.*, **107**, 291, 1947). The present plan is to use 10-inch collimating telescopes of 14 ft. focal length and a 12-inch mirror.

A new meridian circle programme comprising all FK3 stars north of $-27° 30'$ and the supplemental list of FK3 stars, approximately 3000 stars, has been prepared and observations will be commenced in 1954.

Observations were taken with the photographic zenith tube on 180 nights, resulting in 200 clock corrections and latitude determinations. Star positions have been improved by using the P.Z.T. observations along with the meridian circle positions. The probable error for the determination of a clock correction from a single star is of the order $\pm 0^s{\cdot}015$. Latitude reached its highest value, $45° 23' 38''{\cdot}93$, in 1952 August, a minimum value, $38''{\cdot}12$, in 1953 May and a maximum again of $39''{\cdot}0$ in 1953 September.

A new measuring engine for zenith tube plates is nearly completed and will be in use early in the new year. The star images as well as the readings of both micrometers will be projected on to a ground glass screen for easy reading.

Time signals have been broadcast continuously over station CHU on 3330 kc/s, 7335 kc/s and 14670 kc/s. The power of the 7335 kc/s transmitter has been increased to 3000 watts. Two talking clocks have been ordered from France and will be used to announce the time once each minute over the three CHU transmitters.

Main timekeepers comprise four crystal clocks. Two of these, Western Electric Frequency Standards, are used as primary clocks, while the other two control the Muirhead time-signal machines. An additional crystal clock with a ring-cut crystal has been ordered from the British Post Office.

The older time-signal machines are now controlled by the crystal clocks and regulate time signals to the Canadian National and Canadian Pacific Railways, the Bell Telephone Company, the master clocks in the government buildings and seismograph instruments.

Stellar physics.—Analysis of the infra-red spectra of meteors, photographed with objective grating spectrographs at Ottawa, has shown the strong multiplets of O I and N I to be a normal feature of the light of fast meteors in the wave-length range 7000 to 9000 angstroms. The lines of H and Fe II have also been identified in meteor spectra photographed with fast panchromatic emulsions. Evidence of unresolved N_2 bands seems to be present in Perseid spectra.

During the year routine meteor observations were commenced with the two Super-Schmidt meteor cameras at Meanook and Newbrook, Alta. These cameras will be used in a programme of direct photography of meteors, designed to determine densities in the Earth's upper atmosphere.

In 1953 observations of the Perseid and Geminid showers were carried out at Ottawa. A total of 908 exposures with meteor cameras was made at all stations in an observing time of 160 hours. In all 1745 meteors were visually observed. Five new meteor spectra were photographed as well as a number of trails with the direct cameras.

In work with the solar spectrograph the technique of double passing the light, thus diffracting it twice by the grating, was used to attain maximum possible resolving powers. The solar spectrum at wave-lengths near 1 and 4 microns was studied in connection with the measurement of the intensities and wave-lengths of the bands of oxygen, nitrogen and nitrous oxide. Isotopic abundances in the

cyanogen band near 3800 angstroms were also investigated. A wave-length calibration technique for the infra-red was developed through laboratory studies of the nitrous oxide bands.

A theoretical study of the mechanism of explosion crater formation was commenced. Mathematical expressions for representing known crater profiles were developed and the initial conditions required to be known were studied with a view to setting up equations to cover the motion of the ejected material. The problem is complicated by the large number of unknown factors.

Terrestrial magnetism.—Magnetic survey operations were carried out by both ground and airborne parties. Ground parties operated in the Provinces of Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia and on Ellesmere Island in the Eastern Arctic. Measurements of declination, inclination and force were made at 57 stations, of which 20 were repeat and 37 new. In addition, vertical force observations were made at 2 base and 123 field stations during a geophysical investigation of a geological feature at Brent, Ontario, and 1 base and 133 field stations in the environs of Meanook Magnetic Observatory, Meanook, Alberta.

A five-year programme of development of a universal airborne magnetometer was brought to completion. Following test flights and swings over Agincourt and Meanook magnetic observatories, the first survey flights were undertaken with the aid of the R.C.A.F. and completed with satisfactory results. The instrument was employed in making continuous records of declination and of horizontal and vertical force during 15 000 miles of flights passing over all 10 provinces, the Northwest Territories and several of the Arctic Islands.

The compilation and construction of isomagnetic maps of Canada for the epoch 1955·0 reached an advanced stage and those depicting inclination, horizontal force and vertical force were completed. Isogonic and isoporic lines were drawn and magnetic data supplied for 1 373 marine charts and topographical and air navigation map sheets.

The four magnetic observatories situated at Agincourt, Ontario, at Meanook, Alberta and at Baker Lake and Resolute Bay, Northwest Territories continued normal operation. A complete new set of photographic recording variometers was installed at Resolute Bay for recording declination and the north and east components of the field.

Gravity.—Field observations with both gravimeters and pendulums were conducted during the year. The gravimeter work included the study of a considerable area to the west of Hudson Bay, in the vicinity of Chesterfield Inlet, for which aircraft transportation was used. A fairly detailed traverse was also made along the Alaska Highway between Edmonton, Alberta, and Fairbanks, Alaska. In addition, several special flights were made for the purpose of calibrating two long-range geodetic instruments over large changes in gravity. These included flights between Winnipeg and Resolute Bay in the Arctic Islands, and between Edmonton and Whitehorse, Yukon Territory.

During the field season two detailed gravimeter surveys were completed. The first of these was over a salt deposit at Malagash, Nova Scotia, while the second was over a topographic depression near Brent, Ontario, which may be the surface expression of a meteor crater.

The programme of establishing base stations with the Cambridge pendulum apparatus was continued. Observations were made at ten stations between

Lethbridge, Alberta and Fairbanks, Alaska, to extend the line established in 1952 between Mexico City and Winnipeg. During the autumn a connection was made between the national gravity station at Ottawa and the British national station at Teddington.

A publication was completed on the adjustment of a network of principal gravity base stations over a considerable portion of the country. Other publications dealing with the gravity results for specific regions are in course of preparation.

Seismology.—There have been some changes and additions to the regular network of seismograph stations maintained by this Observatory. The Victoria station has been completely re-equipped with Benioff short- and long-period vertical and horizontals, and has been housed in a new vault. A Willmore vertical seismograph has been installed at Shawinigan Falls and a Benioff vertical short-period seismograph at Seven Falls. New temporary stations have been placed in operation at Fernie, B.C., and at Turner Valley and Blairmore, Alberta. The new stations, which are operating Willmore vertical seismographs, will permit an extension of the programme of epicentre location in southern British Columbia.

As a first step in extending the field work of the Division, a radio communication system is being constructed to transmit the output of twelve seismometers into a single recorder over distances up to 30 miles. The equipment is intended for long-range refraction studies. A 3-channel prototype was used to obtain a seismic profile across a suspected meteor crater near Brent, Ontario.

A programme for investigating the direction of faulting in large earthquakes has been continued. Tables, analogous to map projection tables, applicable to earthquakes of any focal depth and permitting use of the phases P, pP, PP, PKP_1, PKP_2 and PcP have been published or are in the press. The tables have been successfully applied to about 40 earthquakes to date.

David Dunlap Observatory, University of Toronto
(*Director, Professor J. F. Heard*)

Radial velocities.—The major programme comprising 1050 stars of type G0 and later in Yale Zone $+25^\circ$ to $+30^\circ$ has been essentially completed and the data are being prepared for publication. A programme of 50 faint high-velocity stars, initiated by Dr Nancy Roman of the Yerkes Observatory, has been nearly completed. A new programme involving suspected members of the cluster about α Persei has been begun in collaboration with Dr O. Heckmann of Hamburg Observatory.

Heard has completed a spectrographic orbit for the eclipsing variable V451 Oph, and Bakos has determined a new orbit for EE Peg. Miss Boshko has a preliminary orbit for the interesting star HD 30353, but the period is so nearly one year that observations will need to be continued over a number of years. Miss Northcott has completed a solution for HD 196133 which has a highly eccentric orbit.

Spectrographic.—Dr P. Wellmann of Hamburg-Bergedorf visited the Observatory for five months and completed a spectrophotometric study of the eclipsing variable 32 Cygni during its 1952 eclipse. Weston made a general study of the spectrum of this same star and discussed improvements in the orbital elements.

Hossack has shown that a characteristic of the spectra of the late G- and early K-type spectroscopic binaries of periods ranging from 15 to 100 days is a strengthening of the hydrogen lines.

Oke has investigated the spectra and radial velocities of the known members, which are brighter than photographic magnitude 10·7, of the galactic cluster NGC 752. Radial velocities have been obtained for several other stars in the cluster field to determine which ones are members of the cluster.

Miss Northcott has investigated the spectrum of HD 201626, a new member of the class of CH stars; it is a high-velocity star of spectral class R5.

Photometric.—Mrs Hogg has completed a revision of her *Catalogue of Variable Stars in Globular Clusters.* This will be issued during 1954, and gives data on about 1400 variables in 70 clusters which have been examined.

Bakos has completed a photometric orbit of EE Peg from photoelectric data.

Stellar luminosities.—Halliday has determined the luminosity classes of 729 late-type stars on the MK system using an oscilloscopic microphotometer built by Hossack. He has studied the luminosity functions of stars between classes G8 and K1 from these data.

Miss Creeper has classified all the stars on the major radial velocity programme on the MK system. These classifications will be published along with the radial velocities.

Equipment.—The Beals-type microphotometer has been redesigned and a pen recorder has been incorporated.

The circuit of the photoelectric photometer is being redesigned to incorporate a pen recorder. Expanded programmes of photoelectric photometry will be undertaken.

Staff.—Professor R. E. Williamson and Mr E. B. Weston have resigned from the staff. New appointments were: Dr Donald A. MacRae as Associate Professor, Dr W. R. Hossack and Dr J. B. Oke as Lecturers.

Publications.—Since the last report, *Comm. D.D.O.* Nos. 31, 32, 33, 34 have been issued.

Dominion Astrophysical Observatory, Victoria

(*Dr R. M. Petrie, Dominion Astrophysicist*)

Staff.—Dr A. McKellar spent the first half of the year at the University of Toronto, lecturing on topics in Astrophysics, and working with Professor H. L. Welsh and his group on problems of Raman spectroscopy and the absorption bands of solid oxygen. Dr Jean K. McDonald has spent the year at the Computational Centre, University of Toronto, studying the application of an electronic computer to problems of model stellar atmospheres. G. J. Odgers went on leave-of-absence in September to study in the Department of Astronomy at the University of California. The following joined the staff, temporarily, during the summer: Professor Joel Stebbins, Lick Observatory; Dr B. N. Moyls, University of British Columbia; Messrs K. McCulloch, H. J. L. Reeves, R. E. Pugh and J. Merner. E. H. Richardson joined the staff as an assistant in December.

Spectroscopy.—The composite spectrum of Capella has been analysed by K. O. Wright, using the high dispersion of the Littrow spectrograph. Spectrophotometric measures have allowed a separation of the spectral profiles of the

components and an estimate of the light-ratio. The spectra are found to be those of normal giants of types G5 and G0. The ratio of brightness of the two stars is 1·25 at λ5500 and the mass-ratio is measured as 1·05. There are not any spectroscopic peculiarities of any importance, the apparent anomalies being caused by the superposition of two many-lined spectra. The component stars agree well with the mass-luminosity relation determined from independent material.

Spectrophotometric measures on the spectra of O stars are being continued by Miss A. B. Underhill. Most of the stars are members of galactic clusters and must be observed with low dispersion. The lines $H\gamma$, $H\delta$, H_9, H_{10}, H_{11} of hydrogen, λ4471 of helium, λλ4542, 4200 of ionized helium, and the broad interstellar feature at λ4430 have been measured for intensity in a large number of spectra. Some preliminary results were presented at the Liège symposium, the conclusion being that the H/He abundance ratio is normal in O stars but that the conventional model-atmosphere calculations are not applicable to these very hot stars.

A considerable number of spectra of the N-type long-period variable, RS Cygni, have been measured by A. McKellar. Radial velocities have been determined from the principal emission lines. The iron lines λ4202 and λ4308 are found to occur strongly in emission, paralleling their behaviour in M and S spectra, and so indicating operation of the resonance mechanism already known to take place in M-type long-period variables.

A long-continued series of observations of the β-Cephei variable, HD 199140, has been concluded by R. M. Petrie. About 500 spectra taken over an interval of twenty-five years have been measured for radial velocity. Line intensities and spectral types have been determined over several cycles. The period of the variation, some $4^h\ 50^m$, is increasing secularly by 0·038 seconds per year. The semi-amplitude of the velocity curve has increased about 10 km/sec in the past quarter century. The spectral lines vary in shape over the cycle but change little in total absorption. The spectral type varies between B1 and B2. The results of this study are being prepared for publication.

An interesting composite spectrum, that of ADS 14864 A, has been studied by G. J. Odgers. The spectrum varies in a striking manner from type K at λ5000 to about B3 at λ4000. It is found that relative Planck functions corresponding to giant K, and main sequence B3, temperatures explain the observed composition.

A spectrophotometric study of the shell star 48 Librae has been completed by Miss A. B. Underhill. The intensities of all the principal lines in the ordinary region have been measured. The spectrum is explained as a combination of a rapidly rotating star, about B3, surrounded by an equatorial ring giving an absorption spectrum corresponding to about supergiant A2.

Line profiles have been determined for $H\alpha$ and $H\beta$ appearing in emission in some Be, shell and cB spectra. Results so far show extended wings to $H\alpha$ in shell spectra, indicating large random motions in the emitted H atoms. A paper on this work has been prepared by Miss A. B. Underhill.

The strength of $H\gamma$ absorption in the spectra of about two hundred B stars has been measured by B. N. Moyls and R. M. Petrie. The stars have been selected so as to give mean parallaxes for testing the Victoria system of spectroscopic absolute magnitudes of the B-type stars.

Stellar motions.—The main radial-velocity programmes have been continued. Observations have been retarded because of adverse weather during the year, but are well advanced. Measuring continues on the B-type spectra and those of the Galactic Pole Cap programme.

R. M. Petrie has completed the revision of wave-lengths for radial-velocity measures on single-prism spectra of type B. The system is the same as that previously set up for A-type and solar-type spectra. It is found that laboratory wave-lengths may be used for most of the spectral features but the diffuse triplets in helium require special care, since the effective wave-lengths depend upon the dispersion employed and upon stellar absolute magnitude.

Spectroscopic binaries.—A. McKellar and H. Reeves have determined orbital elements for the two-spectra binary HD 110533. J. A. Pearce has determined revised orbital elements and dimensions for the systems ψ Orionis, ι Orionis and ADS 6012 A, in each of which a faint secondary spectrum is present. He has also recomputed the orbital elements of α Draconis, after determining and applying a correction to reduce the Ottawa single-prism velocities to the Lick system. Revised orbital elements of π^5 Orionis and orbital elements from 1951–52 observations of AR Cassiopeiae have been calculated by Mrs R. W. Edmonds.

Stellar atmospheric models.—Miss J. K. McDonald is studying the problem of applying the electronic computer to the computation of model atmospheres without using approximations ordinarily employed to reduce labour. The use of this machine has made it possible to undertake an improved method of constructing a model of a non-grey atmosphere, that employing the variational method for solving the integral equation for the source function, previously applied to the case of a grey atmosphere by, among others, Kourganoff and Huang. This method assumes that the monochromatic source function may be represented by an expansion in terms of the exponential integral functions. The equation representing the monochromatic flux in terms of these functions may then be integrated with respect to frequency to provide for each value of optical depth in the atmosphere an equation expressing the constancy of flux as a minimum condition. This set of equations, combined with the equations representing the radiation at any optical depth (over 200 equations in 39 unknowns), may be solved to provide an improved temperature-depth distribution that may be expected upon repetition of the process to converge to a distribution that ensures a constant flux.

In addition to the main problem, tables of the Planck function and of the absorption coefficient for a pure hydrogen atmosphere will be extracted from the machine over a temperature range 15 000 deg. to 50 000 deg. K and in the frequency interval corresponding to 100–22 800 angstroms.

Photometry.—The photoelectric photometer has been improved by the addition of quartz optics, an EMI photomultiplier tube, a radioactive standard light source and a strip-chart recorder. The instrument has shown up well in tests and a first short programme has given colours for 36 B stars.

Seismology.—The western Canada network has been operated continuously. A new instrument vault has been provided at Victoria and new instruments installed in it. Three seismographs have been placed in the Crow's Nest Pass area of British Columbia and Alberta to study rockbursts and earthquakes in the coal-mining area. The 1952 British Columbia earthquakes have been located,

also those up to 1953 June. A study of the crustal behaviour in the Victoria area is being made with the assistance of the Royal Canadian Navy, which has cooperated by dropping a series of depth charges in the waters adjacent to Vancouver Island.

Instruments.—The development of the new stellar spectrograph continues. New chromium-plated slit jaws have been installed and an extended guiding eyepiece with a light-weight control box has been built, adding greatly to the comfort of the observer. Three new gratings have been acquired with excellent blazes and good freedom from scattered light. A new collimator-camera lens of 72 inches focal length has been received and mounted. This lens used with the gratings, in a Littrow form, gives linear dispersions of 8, 4·1 and 2·8 A/mm, respectively, in the first three orders, and a flat field over two four-inch plates. The quartz-fluorite achromatic, of focal length 41 inches, referred to below, also gives very good performance in the Littrow form of the spectrograph.

A quartz-fluorite collimator and quartz prism and camera lens have been obtained and construction of an ultra-violet spectrograph is well advanced. The linear dispersion is 40 A/mm at λ 3400. New cameras have been designed for the ordinary prismatic dispersions. These will be constructed largely of aluminium and will replace the original cameras.

General.—The addition to the office building was completed during the year. The new building offers adequate office and library space, contains a specially planned seismographic section and provides facilities for laboratory and experimental work.

An index of spectrograms has been commenced and is complete from 1937 July to the present. This will make it possible to tell at once whether any particular star has been observed at Victoria and, if so, with which spectrographic arrangement.

The additional space has permitted a complete reorganization of the library into one section of the building. During the year 98 books were bound, and 35 monographs were acquired. The following papers were prepared for publication :

Vol. IX, No. 9. " Hydrogen Absorption Lines in the Spectra of B-Type Stars " by Jean K. McDonald.

Vol. IX, No. 10. " Wave-Length Standards for Radial-Velocity Determinations from B-type Spectra " by R. M. Petrie.

Vol. IX, No. 11. " Spectrographic Studies of the Combination Variables Z Andromedae, BF Cygni, and CI Cygni " by L. H. Aller.

Vol. IX, No. 12. " The Spectrum of the Shell Star 48 Librae " by Anne B. Underhill.

Vol. IX, No. 13. " Spectrographic Orbital Elements for the Binary H.D. 110533 " by Andrew McKellar and Hubert Reeves.

Contribution No. 30. " The Relative Abundance of Hydrogen to Helium in Stars " by Anne B. Underhill.

Contribution No. 31. " Convergent Point and Space Motion of the Ursa Major Cluster " by R. M. Petrie and B. N. Moyls.

Contribution No. 32. " On the Problem of the Hα Emission in the Shell Stars " by Anne B. Underhill.

Contribution No. 33. " Spectra of the Late N-Type Stars in the Ultraviolet, Violet, and Blue-Green Regions" by P. Swings, A. McKellar and K. N. Rao.

Contribution No. 34. "Luminosities of the B Stars from Spectroscopic Measurements" by R. M. Petrie.

Contribution No. 35. "On the Strength of the Helium Lines in the O-Type Stars" by Anne B. Underhill.

Contribution No. 36. "The Secondary Component in the Spectrum of Capella" by K. O. Wright.

Union Observatory, Johannesburg

(Director, Dr W. H. van den Bos, Union Astronomer)

The $26\frac{1}{2}$-inch refractor has been used on 209 nights for interferometer and on 60 nights for micrometer measures of double stars. The interferometer work is done by Dr Finsen, the micrometer work by Dr van den Bos and Mr Churms.

Plates taken with the Franklin-Adams telescope by Messrs Johnson, Bruwer and Churms:

Minor Planets		353 plates
Comets		68 plates
Variable Stars		51 plates
Miscellaneous		1 plate
	Total	473 plates

In addition, 116 plates for minor planets and 2 for comets were obtained with the Rockefeller telescope of the Leiden southern station by kind permission of the Leiden Observer.

With the 9-inch and 6-inch refractors, occultations of stars by the Moon were observed on 34 nights by Messrs Bruwer and Churms, while the occultation of Antares and its companion on March 7 was recorded photoelectrically with the Leiden telescope by a team of observers.

The transit of Mercury on November 14 was observed with 3 telescopes by Messrs Finsen, Bruwer, Seligmann and Churms.

Counts of sunspots were made on 288 days.

During the year 1286 visitors were admitted on 42 nights.

Members of the Transvaal Branch of the Astronomical Society of South Africa assisted in receiving the visitors and preparing exhibits, and made visual observations of planets and variable stars with the 9-inch and 6-inch refractors.

The Time Service is operated by Messrs Hers and Seligmann.

Circular No. 113 was published and distributed.

Dr Walraven, Leiden Observer, returned to Leiden in October and was relieved by Dr Muller, who arrived in August.

Astronomers Code, Cousins, Evans, Hirst, Hoffmeister and Mrs Hoffmeister, Houck, Morrisby, Russo, Smith and Mrs Smith, Stoy, Thackeray, Voûte and Wanick visited the Observatory.

Radcliffe Observatory, Pretoria

(Director, Dr A. D. Thackeray, Radcliffe Observer)

Equipment.—The performance of the Cassegrain photometer has been improved, partly through the acquisition of a sensitive 1P21 cell. With the

cooperation of the Cape Observatory this instrument is also being adapted for use with an EMI cell.

A perforated blazed grating, $2\frac{1}{2} \times 3$ inches, has been obtained from the Bausch and Lomb Optical Co., for use in the Newtonian spectrograph. A 6×8 inch grating has been ordered from the same Company for use in a Coudé spectrograph, for which plans have been prepared.

The Cassegrain secondary has been re-aluminized during the year; after slightly more than two years' use very rapid deterioration in the coat set in owing to unknown causes. A considerable advance has been made with plans for a large aluminizing plant.

Buildings.—Plans have been prepared for a small building to accommodate visiting astronomers from the Cape Observatory.

Observations. (*a*) *Radial velocities.*—The first stage in the programme of observing southern stars of type O to B5 is complete and results are being prepared for publication. This work provides 148 new velocities and includes re-observation of some 30 stars whose velocities have already been measured by the Lick or other Observatories. Eight double-line binaries have been found; these stars and a few additional doubtful cases will be investigated further during the coming season. One of them, HD 77464, has already been observed intensively and a preliminary period derived. In addition to securing an overlap with other Observatories on standard stars, a check on the zero of the radial velocity system is being made through observations of Vesta and other objects in the solar system.

Observations of 100 B0 to B2 stars with $m_0 - M > 11$, as indicated by Oosterhoff's photoelectric measures, have been begun.

Observations of the two components of α Centauri, which yield an accurate parallax of the system, have been submitted to the Society.

Good progress has been made with obtaining spectra of individual members of 47 Tucanae.

Objects in the Magellanic Clouds, including 30 Doradus, globular clusters and some of the brightest Cepheid variables, have been observed.

(*b*) *Stellar spectroscopy.*—Observations of the S-type star π^1 Gruis and its faint companion, which indicate that the primary is not a supergiant, have been communicated to the Society.

A paper on the spectrum of the helium star HD 168476 has been submitted to the Society. 206 absorption lines between 3700 and 6700 A have been measured: He I, C II and Ne I are prominent. The large number of faint lines present support the conclusion that H is markedly deficient with a consequent increase in transparency of the atmosphere.

A spectroscopic survey of 59 southern N-type stars in the region of 6700 A has been completed. One of these only, T Ara, shows the lithium line 6708 unusually strong. The results were communicated to the Liège conference on stellar abundances of elements.

Spectra of the variable BL Tel taken before and during minimum, in combination with photoelectric observations at the Cape Observatory by A. W. J. Cousins, show that it is a supergiant eclipsing system.

Dr A. D. Code and Mr T. E. Houck of the University of Wisconsin, representing an expedition from the Washburn Observatory, used the Cassegrain spectrograph, chiefly with the $f/2$ camera, to obtain spectra of 125 southern

B stars for the purpose of luminosity classification and tracing out the spiral structure of the southern Milky Way. Other objects studied by these observers included 22 stars in NGC 6231, γ Vel, α Ara and a few of the brightest stars in the Magellanic Clouds. In combination with Radcliffe staff infra-red spectra of some stars and the planetary NGC 7009 were obtained on Z emulsion; in the latter object the line He 10830 was observed in emission.

Notes on the spectra of RR Pic, o Ceti (at minimum) and 30 Dor have been published in *M.N.A.S.S.A.*

The spectrum of RR Tel in 1953 contained a number of unidentified lines in the region of 5000 A which are probably due to [Fe IV].

Other objects of special interest which are being studied spectroscopically include the following: S Doradus, the eclipsing variable AL Velorum, S Indi and other Me variables, S Aps and other R CrB variables, P Cygni objects and various portions of the halo surrounding Eta Carinae.

(*c*) *Direct photography.*—A preliminary revision of the distance modulus of the Magellanic Clouds on the basis of RR Lyrae variables in NGC 121, 1466, 1978 has been published in *Nature*, **171**, 693, 1953. Work on these clusters has continued, and more RR Lyrae variables have been discovered in another cluster in the Large Cloud. A total of 79 plates have now been obtained in a central field in the Small Cloud which should provide statistics on variables in that region down to a limit near 20th magnitude.

A final series of plates of two regions in the Sagittarius Cloud has been obtained by Dr Th. Walraven and A. Muller of the Leiden Observatory and by Radcliffe staff.

At the request of Dr S. Herrick, 6 further plates of the minor planet Icarus were obtained during August. The positions as derived from measurements kindly undertaken by members of the Cape Observatory staff again agree well with Dr Herrick's ephemeris.

(*d*) *Photoelectric photometry.*—Considerable time has been devoted to the developmental side of this work. The eclipsing variable RT Scl has been observed in two colours. Other observations have included the brightest stars in 47 Tuc, stars in E regions and HD 168476.

The Washburn observers, using a photometer at the Newtonian focus, observed 95 stars in E regions, S.A. 68, the Small Cloud, NGC 6231 and other clusters including NGC 121.

Measures of the relative brightness of the night sky in various directions were reported to the Pretoria City Council, as a result of which the Council have cooperated by fitting much more effective shades to the street lights in the nearest Pretoria suburb.

General.—The daytime occultation of ϵ Geminorum by Mercury in June was observed visually with difficulty in poor conditions.

Evidence has been adduced in favour of the excitation of Ti 4372 in Me variables by the line Mg II 2802.

The telescope was used on 294 nights during the year. For the second year in succession the total number of effective hours of observation has slightly exceeded 2600. The season was remarkable for a drought, during which no rain was recorded on 143 successive days.

Visitors.—The cooperation scheme with the Cape Observatory has been extended for a further period of five years.

The following visiting astronomers have used the telescope: from the Cape Observatory, S. Archer, D. S. Evans, A. Menzies, A. Morrisby (throughout the year), T. W. Russo; from the Leiden Observatory, Th. Walraven, A. Muller; from the Union Observatory, J. Churms; from the Washburn Observatory, A. D. Code and T. E. Houck. J. D. Fernie, student of Cape Town University, worked at the Observatory for a few weeks. In addition the following have visited the Observatory; C. Hoffmeister, H. Knox-Shaw, Henry and Elske Smith, R. H. Stoy, F. J. M. Stratton, G. Whipple and astronomers from the Union Observatory, Johannesburg. It is estimated that about 750 members of the public visited the Observatory during the year; the majority of them viewed celestial objects through the Radcliffe reflector on the six open nights allocated to this purpose.

Nizamiah Observatory, Hyderabad
(Director, Dr Akbar Ali)

Astrographic equatorial.—The 8-inch photovisual object glass of the Astrographic Equatorial which was sent to Messrs Cox, Hargreaves and Thomson Ltd. for re-figuring and polishing is expected back here in the course of the next year.

51 plates were taken in the ecliptic regions for cometary and minor planet work with the 5-inch Astro Camera.

The survey and reduction of photographic doubles in the southern zones -17° to -23° have been completed. It is proposed to coordinate the results for publication in one volume.

Grubb equatorial.—A few micrometrical observations of the minor planet Ceres and physical observations of comet 1953 h were obtained. 32 occultations of stars by the Moon, including those of 13 faint stars, were observed during the year. These have been reduced and the results communicated to H.M. Nautical Almanac Office for incorporation in the annual discussion.

The total eclipse of the Moon on 1953 January 29–30 was observed. During the period of totality 5 occultations of faint stars were observed.

Spectroheliescope.—The Sun was observed with this instrument on 150 days during the year for two hours on average per day. Two flares of intensity 1 and one of intensity 2 were observed. Dark filaments were also observed with eight shifts towards violet, four towards red and one towards both. The data for solar flares have been sent for incorporation in the *Quarterly Bulletin of Solar Activity* (Zürich).

Publications.—The following papers were sent for publication: (1) " Occultations of stars by the Moon observed at the Nizamiah Observatory during the year 1952 " (*M.N.*, **113**, No. 2); (2) " Observations of the Total Eclipse of Moon on 29–30 January 1953 made at the Nizamiah Observatory, Hyderabad " (*Journal des Observateurs* (in press)).

New equipment.—An order for an electric drive for the astrographic telescope has been placed with Messrs Cox, Hargreaves & Thomson Ltd. It is expected to be ready for delivery by next year.

A stellar photometer for photographic photometry is being made locally and is nearly finished as far as the metallic parts are concerned.

A micrometrical attachment for the follower telescope of the 8-inch astrograph has also been made locally for guiding on moving objects like comets, etc.

Miscellaneous.—Lectures in practical astronomy were given to the graduate classes of the Osmania University.

The seismological work of the Observatory continued as usual.

Dr Vainu Bappu has been working as guest investigator since 1953 July.

Kodaikanal Observatory, Kodaikanal

(Director, Dr A. K. Das)

General.—Concrete proposals were submitted to the Government of India for acquiring for this Observatory a polarizing monochromator of the latest type, an 8-inch coronagraph and a large solar telescope and spectrograph.

It is hoped that Government sanction for the purchase of these instruments will be received shortly.

The Standing Advisory Board for Astronomy and Astrophysics in India was reconstituted by the Government for another period of three years.

International cooperation.—Exchange of spectroheliograms with foreign observatories was continued. 773 *K*-disk spectroheliograms for the period 1951 January to 1953 September were sent to the Director, The Observatories, Cambridge University. Eight photoheliograms together with the relevant zero plates for certain specified dates in 1951–52 were sent to the Royal Greenwich Observatory on request. 32 H-alpha and 42 *K*-disk spectroheliograms for the period 1952 July to 1953 June were received from Meudon Observatory, France. 124 H-alpha disk spectroheliograms for the period 1951 July to 1953 June and 103 *K*-prominence spectroheliograms for the period 1952 January to 1953 June were also received from the Mount Wilson Observatory, U.S.A.

Quarterly statements relating to solar flares were sent as usual to Dr L. d'Azambuja of the Meudon Observatory and to Mr H. W. Newton of the Royal Greenwich Observatory.

The practice of broadcasting daily URSIGRAMMES relating to solar and geomagnetic activity and of issuing warnings for expected ionospheric and geomagnetic disturbances was continued.

With effect from 1953 April the practice was adopted of supplying to the Chief, Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D.C., U.S.A., monthly median values of F2 layer critical frequency and the maximum usable frequency factor for 3000 km transmission as observed at Kodaikanal. Monthly median values of all other ionospheric parameters are supplied to him quarterly.

Routine observations.—Weather conditions during the year were less favourable for solar observations than in the previous year. Photoheliograms were taken on 296 days and visual observations of the Sun were made on 295 days as against 306 and 319 days respectively in the previous year. H-alpha disk, calcium disk and calcium prominence spectroheliograms were obtained on 285, 273 and 254 days respectively as compared with 301, 282 and 269 days in 1952. Observations with the spectrohelioscope were made on 283 days.

The average definition of the Sun's image on a scale in which 1 is the worst and 5 the best was 3·1 as compared with 2·8 in 1952. There were 38 days on which the definition was 2 or less and 61 days on which the definition was 4 or more.

Sunspot activity.—There was a further steep decrease in sunspot activity during the year, the decrease being 60 per cent compared with 1952. There were 142 spot-free days out of the total of 296 days of observation as against 38 spot-free days in 1952. The yearly mean latitude of all the observed spot-groups in the northern and southern hemispheres was 9° and 8°·4 respectively as against 9°·5 and 9°·7 for the previous year. There were five groups in the north and four in the south hemisphere within the latitude range 0°–5°.

Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of new spot-groups	N	6	1	4	1	1	3	Nil	3	1	1	Nil	Nil	21
	S	2	Nil	3	2	1	1	1	1	1	3	1	2	18
Total		8	1	7	3	2	4	1	4	2	4	1	2	39
Mean daily numbers		2·08	0·40	0·65	1·20	0·87	1·12	0·50	1·35	0·87	0·37	0·14	0·09	0·82
Kodaikanal daily relative number		27·6	4·4	7·5	20·6	11·3	15·0	7·0	17·0	10·3	5·9	1·6	1·0	10·77

Solar flares.—Three solar flares, all of intensity 1, were observed during the period.

Radio astronomy.—Recording of solar noise at 100 Mc/s was continued with a Radio Telescope with a twin Yagi type of antenna.

Geomagnetic observations.—Continuous photographic recording of H, V and D with Watson and La Cour magnetographs was continued. Visible recording of the horizontal force with an Askania Magnetic Field Balance was commenced in April. Absolute measurements of H and D were made once a week with a Kew Magnetometer and observations of inclination on five days in the week with an earth inductor.

During the year 15 magnetic storms with range in $H > 150\gamma$ were recorded as compared with 25 in 1952. Of these five were of the sudden commencement type. No storms were recorded with ranges in H exceeding 400γ.

Ionospheric observations.—Regular ionospheric observations during daylight hours with the Automatic Ionosphere Recorder were continued.

Cosmic ray observations.—Photographic recording of cosmic ray intensity was continued using a Kolhörster apparatus.

Seismology.—The Milne–Shaw Seismograph (E–W component) recorded 122 earthquakes.

Meteorology.—Meteorological observations with all the visual and self-recording instruments were carried out as usual.

Library.—36 books and 832 periodicals were added to the library.

Research work.—Under the Research Training Scheme sponsored by the Ministry of Education, Government of India, two senior and two junior scholars were working in the Observatory.

The following problems in solar physics and geophysics were investigated during the year :—

1. Experimental study of centre-to-limb variation in the intensity of the continuous spectrum of the Sun;
2. Measurement of the difference of temperature between the equator and the pole of the Sun by spectroscopic method;
3. Study of radiation flux across sunspots;

4. Investigation of the sporadic E layer at Kodaikanal;
5. Investigation of very long sequences of geomagnetic activity associated with solar M regions;
6. Lunar stratification of the F2 layer of the ionosphere;
7. Variation in the D layer absorption.

Publications.—The following notes and papers were published or sent for publication during the year :—

(1) " Temperature at Pole and Equator of the Sun ", *Vistas in Astronomy.*
(2) " Temperature at Pole and Equator of the Sun " (Abstract), *Nature.*
(3) " Eruptive Prominence of 1953 February 26 and associated Radio Noise Burst ", *Nature.*
(4) " Can Matter be Created out of Cosmic Radiation ? ", *Die Naturwissenschaften.*
(5) " Radio Noise Bursts from Solar M-Regions ", *Nature.*
(6) " Geomagnetic Activity and the Sunspot Cycle ", *Nature.*
(7) " The Sporadic E Layer at Kodaikanal ", *Journal of Geophysical Research.*
(8) " Very long sequences of Geomagnetic Activity and its annual Variation ", *Nature.*
(9) " Study of the Continuous Solar Spectrum in the Visible Range ", *Annales d'Astrophysique.*
(10) " Radiation Flux in Sunspot Umbrae ", Paper II, *Zeitschrift für Astrophysik.*
(11) " Study of Diurnal Variation of the Horizontal Component of the Magnetic Field at Kodaikanal ", *Indian Journal of Meteorology and Geophysics.*
(12) " Kodaikanal Observatory Bulletin No. 136 for the second half of 1951 giving the summary of the results of solar and magnetic observations."
(13) Kodaikanal Observatory Bulletin No. 137 : " Discussion of the results of observations of solar prominences made at Kodaikanal from 1904 to 1950 ".
(14) " Kodaikanal Observatory Bulletin No. 138 for the first half of 1952 giving the summary of the results of solar and magnetic observations."
(15) Quarterly synopsis of solar, geomagnetic and ionospheric observations made at Kodaikanal : *Indian Journal of Meteorology and Geophysics.*
(16) Annual Report of the Kodaikanal Observatory for 1952.

Commonwealth Observatory, Mt Stromlo

(Director, Professor R. v. d. R. Woolley, F.R.S., Commonwealth Astronomer)

During the year the new workshop, replacing that destroyed by fire in 1952 February, was completed, and it is now in use. The foundations for the 74-inch telescope have been completed and surrounded by a steel building, but the dome has not yet arrived from England. The Yale–Columbia building has also been completed except for the dome, which is being fabricated in Sydney. Some progress has been made with the 50-inch telescope, whose mechanical parts are in the final stages of assembly, but the secondary mirror (for the Gregorian combination with the spherical primary mirror) has not yet been received. The 3 prism spectrograph, which exhibited some flexure when tested early in the year, has received considerable workshop attention, the main frame being greatly strengthened. It is now considered to be satisfactorily free from flexure.

Observations for time have been continued as in previous years, and a full programme of astrophysical work, details of which will be given in the Annual Report of the Observatory, has been carried out with the Reynolds 30-inch reflector, the Oddie 9-inch refractor and the recently acquired Catts 20-inch reflector. The latter telescope has been made available for a considerable part of the year to the Yale–Columbia observers, Professor Schilt and Mr J. Jackson.

Professor Schilt left the Observatory on 1953 April 17. The Observatory was visited from 1953 May 27 to June 17 by Dr T. Dunham, Jr. Dr W. G. Baker has been appointed Officer in Charge of the Ionospheric Prediction Service in succession to the late Dr A. L. Green. Dr Baker commenced duty in May.

Riverview College Observatory, Riverview, N.S.W.

(*Director, T. N. Burke-Gaffney, S.J.*)

The exceptionally dry winter of 1953 made it possible to take over 700 plates for the variable star programme. This is a greater number than has been taken in any one year since 1938. Due to the same cause, more than the usual number of occultations were also observed. In the course of the year, Reprints Nos. 3, 4 and 5 were distributed. Astronomical and geophysical information was supplied to public bodies and private enquirers when requested. Much use was made of the library facilities by persons and institutions to whom astronomical literature is not otherwise easily available. Parties of visitors were conducted around the observatory at regular intervals. Extensive and much-needed alterations and repairs were carried out during the year.

Sydney Observatory

(*Director, Harley Wood, Government Astronomer*)

The work on the Astrographic Catalogue has been continued, Volume 34 of the Sydney Section having been printed and distributed. Several more volumes are ready to hand to the printer. Volumes 4 and 5 of the Melbourne Catalogue, the work on which was undertaken at the request of the International Astronomical Union, have been completed and are deposited at Paris Observatory until a beginning can be made on the publication, which is to be carried out for the Union under the direction of Dr J. Baillaud.

The programme of observations of occultations predicted in the *Nautical Almanac* has been continued. The results for 1952 have been published, and those for 1953 are being reduced.

A new departure in the work of the Observatory has been the commencement this year of observations of minor planets. We have been observing planets which culminate south of the equator, and aided by a period of fine weather during the winter season we have made a satisfactory start on this work which we hope to make a permanent feature of our programme.

The civil and educational work of the Observatory has continued as in previous years.

Radiophysics Laboratory, Sydney

(*Director, Dr E. G. Bowen*)

This report covers the radio astronomy part of the Laboratory's programme. This is carried out under the direction of Dr J. L. Pawsey.

A most interesting development is the construction by B. Y. Mills (see Mills and Little) of a new form of radio telescope, or radiometer. The system utilizes an aerial in the form of a cross and gives a " pencil-beam " response with a resolution approximating to that of a square aerial of side equal to the length of the cross.

Because the actual aerial occupies a relatively small area (relative to this square) it is practicable to make the linear dimensions very great, thus obtaining very high angular resolution. It is generally realized that current radio surveys of the sky are seriously deficient in angular resolution and this instrument is being developed in an attempt to overcome this lack. Last year a pilot model of the Mills radiometer, of length 120 feet, was successfully completed. A large model of length 1500 feet, to work at a wave-length of $3\frac{1}{2}$ metres, is now under development. If successful, it will have an angular resolution approximating that, at the same wave-length, of a paraboloid with an aperture 1500 feet in diameter, i.e. a little over $\frac{1}{2}°$. The beam will be swung north and south, roughly between declinations $-90°$ and $+20°$, by means of phase adjustments to aerials in the north–south arm of the cross.

Another, unrelated, development may connect two previously distinct sections of the Laboratory's programme, rain physics and astronomy. Dr Bowen has discovered that, for a number of places distributed over the world, excessive rainfall has shown a tendency, over the last fifty years, to occur within a day or so of certain preferred calendar dates. Meteor showers are one of the few phenomena which recur in this way and a possible connection between excessive rainfall and the incidence of meteoric dust on the Earth has been suggested. If this suggestion is substantiated, a most interesting connection between astronomy and meteorology will have been established.

Notes on other important investigations in progress are given below and further investigations are indicated by the titles in the list of published papers.

1. *Cosmic radio waves*

(*a*) 1420 *Mc/s atomic hydrogen emission.*—A series of observations was taken of the hydrogen line emission over the Clouds of Magellan. These are the first external galaxies to be examined using this radiation. The observations show that for both Clouds the hydrogen emission is extended over a greater area than is the light. They also indicate that, despite optical evidence of much more dust in the Large Cloud, the hydrogen content is very similar in each. A large amount of data on line-of-sight velocities was obtained, leading to a measure of the rotational characteristics, and hence the mass, of each Cloud.

Work on the development of a multi-channel receiver is continuing.

(*b*) *Discrete sources.*—Observations of the one-dimensional angular distribution of brightness across discrete sources have shown that the distributions are complex, and have emphasized the necessity for adequate two-dimensional studies.

2. *Solar radio waves*

(*a*) *Interferometer observations on a wave-length of* 21 *centimetres.*—The second multi-element Christiansen interferometer with a resolution of 3 minutes of arc was completed and north–south and east–west one-dimensional distributions of radio brightness over the solar disk are being obtained. The two-dimensional brightness distribution for the quiet Sun is being derived and the nature of the disturbed bright areas which tend to occur in the vicinity of sunspots and "bright hydrogen" areas is being studied.

(*b*) *Observations of the dynamic spectra of metre-wave-length bursts.*—Sufficient observations of dynamic spectra in the frequency range 40 to 240 Mc/s have now been obtained to permit a study of outbursts and isolated bursts. The most interesting feature is the occurrence of second harmonics, firm evidence for an

origin in oscillating electrical charges under non-linear conditions. Observations of certain bursts are interpreted as indicating the emission of high-energy particles (velocity $\simeq \frac{1}{4}c$) from the Sun.

(*c*) *Routine observations.*—Regular observations of intensity are taken on frequencies of 62, 98, 200, 600, 1200, 3000 and 9400 Mc/s and the results submitted to the *Quarterly Bulletin on Solar Activity*. The radio section of this Bulletin is edited by S. F. Smerd of this Laboratory.

3. *Effects of the terrestrial ionosphere*

The " twinkling " of " radio stars " has been studied at single frequencies by observations of " radio stars " rising over the sea. This has led to the conclusion that, contrary to currently accepted ideas, the E region of the ionosphere contributes significantly to this phenomenon. The phenomenon is also being studied over a continuous range of frequencies using the radio spectrometer which is used for solar bursts.

4. *Publications during* 1953

Bolton, J. G. and Slee, O. B., " Galactic Radiation at Radio Frequencies. V. The Sea Interferometer ", *Aust. J. Phys.*, **6,** 420, 1953.

Bolton, J. G., Slee, O. B. and Stanley, G. J., " Galactic Radiation at Radio Frequencies. VI. Low Altitude Scintillations of the Discrete Sources ", *Aust. J. Phys.*, **6,** 434, 1953.

Bowen, E. G., " The Influence of Meteoritic Dust on Rainfall ", *Aust. J. Phys.*, **6,** 490, 1953.

Bracewell, R. N., " The Sunspot Number Series ", *Nature*, **171,** 649, 1953.

Bracewell, R. N., " A New Instrument in Radio Astronomy ", *The Observatory*, **73,** 200, 1953.

Christiansen, W. N., " A High-Resolution Aerial for Radio Astronomy ", *Nature*, **171,** 831, 1953.

Christiansen, W. N. and Warburton, J. A., " The Distribution of Radio Brightness over the Solar Disk at a Wavelength of 21 Centimetres. I. A New Highly Directional Aerial System ", *Aust. J. Phys.*, **6,** 190, 1953.

Christiansen, W. N. and Warburton, J. A., " The Distribution of Radio Brightness over the Solar Disk at a Wavelength of 21 Centimetres. II. The Quiet Sun—One-Dimensional Observations ", *Aust. J. Phys.*, **6,** 262, 1953.

Davies, R. D., " Radio Observations at the Time of an Ascending Solar Prominence ", *Nature*, **172,** 450, 1953.

Gardner, F. F. and Pawsey, J. L., " Study of the Ionospheric D-Region Using Partial Reflections ", *J. Atmos. Terr. Phys.*, **3,** 321, 1953.

Mills, B. Y. and Little, A. G., " A High-Resolution Aerial System of a New Type ", *Aust. J. Phys.*, **6,** 272, 1953.

Mills, B. Y., " The Radio Brightness Distributions over Four Discrete Sources of Cosmic Noise ", *Aust. J. Phys.*, **6,** 452, 1953.

Pawsey, J. L., " Radio Astronomy in Australia ", *J. Roy. Astr. Soc. Canada*, **47,** 137, 1953.

Pawsey, J. L. and Smerd, S. F., " Solar Radio Emission ", *The Solar System*, Ed. G. P. Kuiper, Vol. 1, Ch. VII, University Press, Chicago, 1953.

Piddington, J. H. and Davies, R. D., " Origin of the Solar Corona ", *Nature*, **171,** 692, 1953.

Piddington, J. H., " Thermal Theories of the High-Intensity Components of Solar Radio-Frequency Radiation ", *Proc. Phys. Soc.* B, **66,** 97, 1953.

Piddington, J. H., " Theories of Solar Phenomena Depending on Sunspot Fields Moving in the Chromosphere and Corona ", *M.N.*, **113,** 188, 1953.

Wild, J. P., Murray, J. D. and Rowe, W. C., " Evidence of Harmonics in the Spectrum of a Solar Radio Outburst ", *Nature*, **172,** 533, 1953.

Wild, J. P., " Techniques for the Observation of Radio-Frequency Radiation ", *The Solar System*, Ed. G. P. Kuiper, Vol. 1, Ch. IX, Sec. 10, University Press, Chicago, 1953.

Perth Observatory

(*Director, Mr H. S. Spigl, Government Astronomer*)

The Western Australian standard time service has been maintained, and the ONOGO signal broadcast from Applecross Wireless Station, as well as hourly and other time signals distributed.

The Milne-Shaw horizontal seismograph record is complete, and was distributed in quarterly bulletins to 57 cooperating stations. Preliminary data of movements within 5000 km of Perth were cabled to the United States Coast and Geodetic Survey through the American Consul. Arrangements are being made to install seismological instruments for a research programme in cooperation with the Lamont Observatory, University of Columbia.

Visitors were admitted on the average of one afternoon and two evenings per week during the year with the exception of the winter months of June, July and August.

The Observatory provides facilities for the Astronomical Society of Western Australia, including section meetings, field nights and Council meetings being held at the Observatory.

Occultations were observed and quarterly results sent to H.M. Nautical Almanac Office. Tide tables for Port Hedland and the north-west coast and appropriate astronomical data were completed for printing. A large number of tables of astronomical phenomena were distributed for various places throughout the State, and information furnished for the Press, legal and general enquiries.

Geophysical Observatory, Christchurch, N.Z.

(*Director, Mr J. W. Beagley*)

Recordings of ionospheric conditions at Christchurch, Rarotonga and Campbell Island, and of cosmic radiation at Christchurch have been maintained.

Because of a rising noise level at Lincoln (Christchurch) the ionosonde has been shifted to Godley Head. It is proposed to send the reserve recorder at Godley Head to Rarotonga.

Current ionospheric projects are on recombination and attachment coefficients in the F layer and on the distribution of ionization with height.

The MU. 2 cosmic radiation recorder has been fitted with new scaling circuits and mounted on a rotatable turn-table. It is to be used now for an experiment on the E.-W. asymmetry.

Analysis of data previously taken by the MU. 2 recorder has shown a N.-S. asymmetry greater than that found in other parts of the world.

The reduction for lunar variations of 5 years' magnetic data for Amberley (Christchurch) has been completed. No explanation has been found for the occurrence of the very large semi-diurnal component of vertical force. A more accurate analysis by the Chapman-Miller method of 22 years' Z data has been commenced.

The earth-current programme has been discontinued.

Carter Observatory, Wellington, N.Z.

(Director, Mr I. L. Thomsen)

Weather conditions during 1953, in New Zealand, were so poor for the whole year that nearly all astronomical projects were hampered.

From February to December, lectures and telescope demonstrations on clear evenings were given to the public on Friday evenings. Attendances totalled 1456. In addition, lectures were given to several societies and a number of popular newspaper articles supplied to the press.

As the headquarters of the Royal Astronomical Society of New Zealand, the Observatory has given as much assistance as possible to amateurs, and the lecture room has been made readily available for meetings.

The loan of a pendulum clock from the Seismological Observatory and a combined chronograph and radio receiving set from the Lands and Survey Department have enabled the Observatory for the first time to maintain a sufficiently efficient time-keeping system for astronomical work.

Sunspot observations have been continued by projection on a 25-cm disk with a 5-inch refractor, by photography on interesting spots with the 9-inch refractor and a Barlow lens, giving an image of 10 cm diameter, and by visual observation with the 9-inch. These, together with observations received from several selected amateurs, have been used to deduce Wolf sunspot numbers reduced to the Zürich scale. Monthly mean values of sunspot numbers during the year were as follows:—28·1, 3·8, 9·5, 25·1, 11·5, 18·8, 7·7, 25·0, 16·6, 6·7, 1·5, 2·2. Detailed reports were forwarded to Zürich Observatory.

Spectrohelioscope observations were made when possible, but no unusual phenomena observed.

Occultation observations were made whenever possible, and also collected from selected amateurs. These are in process of partial reduction for forwarding to H.M. Nautical Almanac Office.

Five photographs were taken with the 9-inch of the Eta Carinae region and a preliminary examination shows Eta to have been about magnitude 6·7 during the year. Eleven photographs of the Moon were taken with the 9-inch and Barlow lens, for the commencement of a series of plates under all degrees of illumination. One photograph of the Harvard Region E7 and three experimental plates completed all the photography possible during the year.

Aurorae during the year decreased to such an extent as to produce almost a dearth in the New Zealand region. However, work has proceeded on the analysis of past work, and a detailed study is almost completed of the method of measurement of parallax photographs. The auroral work is now being supported by the Air Force Cambridge Research Center, U.S.A.

Short-term ionospheric disturbance forecasts were issued to the Post and Telegraph Department, New Zealand Broadcasting Service, and Royal New Zealand Navy. Owing to the very low level of solar activity, however, these forecasts have been entirely dependent on the 27-day recurrence pattern, deduced from radio condition reports provided by the services, as well as magnetic index figures obtained from the Geophysical Observatory, Christchurch.

Information has been supplied to the press, radio, legal firms, architects and others when requested.

Godlee Observatory

(Curators, Manchester Astronomical Society)

During 1953 Godlee Observatory has been open to members of the Manchester Astronomical Society on Thursday evenings throughout the year, and many parties of visitors from educational, cultural and youth organizations, totalling several hundred persons, have been welcomed. When weather permitted, observational work was done and the instruments were explained, and when conditions were unfavourable lantern lectures were given. In addition the demand for lectures has been increasingly active, and has been met in full by Wardens of the Observatory.

As in previous years, routine solar observations for sunspots and faculae have been carried out daily, weather permitting, and these have been supplemented by observations made by members of the Manchester Astronomical Society with their own instruments.

A number of lunar and planetary drawings have been made, but attempts to time occultations have been much interfered with by cloud. A programme of double star work has been commenced and, with the overcoming of some early trouble with the micrometer, will, it is hoped, be accelerated.

In September, on the occasion of the Jubilee of the Manchester Astronomical Society, the Observatory was open on two evenings to the general public, and together with an exhibition of instruments, astronomical drawings and films, attracted a very large number of visitors.

Observatory of the Hampstead Scientific Society

(Secretaries, Miss M. Davies-Scourfield, Mr H. Wildey)

The 6-inch Cooke refractor has been much used by members and the general public.

Two new demonstrators have volunteered to open the Observatory to visitors on Thursday evenings from $20^h\ 30^m$ to 22^h when the weather is clear. This is in addition to the usual Saturday demonstrations.

Mr R. Barker's Observatory, Cheshunt, Hertfordshire

Never have worse seeing conditions prevailed at Cheshunt than during this most unsettled year. It has been very difficult to accomplish any definite work in the few opportunities that occurred, except to locate a new cleft in the lunar walled plain Vendelinus, and to confirm a previous discovery of a system of difficult clefts north-west of Promontory Laplace.

Dr J. L. Haughton's Observatory, Charmouth, Dorset

Ten lunar occultations were observed and a few photographs were taken in an unsuccessful attempt to locate comet Pons-Brooks. The observatory was open to the public from time to time and was visited by 62 people. Meteorological observations were carried out as usual.

Mr M. B. B. Heath's Observatory, Kingsteignton, S. Devon

Planetary work was considerably curtailed by haze and cloud. Daylight observations of Mercury were made on 20 days and of Venus on 59 days. Jupiter was observed on 16 nights, transits, occultations and eclipses of satellites I, II and III being timed for duration. Saturn was observed on 33 nights, special attention being paid to relative intensities of globe and ring features.

Mr F. M. Holborn's Observatory, Peaslake, Surrey

During 1953, 2211 observations of 73 variable stars and novae were made on 149 nights and several comparison star sequences were reviewed. The Sun was observed on 213 days for spot counts and naked-eye spots. All the records were communicated to the British Astronomical Association except those of γ Cassiopeiae which were reserved for the Norman Lockyer Observatory.

Mr Patrick A. Moore's Observatory, East Grinstead, Sussex

The main instrument (the 12½-inch reflector) was completely overhauled during 1953, and a new mirror, made by Mr H. Wildey, was installed in December. Observations made have therefore been fewer than usual, and confined almost entirely to the Moon; results have been communicated to the B.A.A. It is hoped to erect a dome in early 1954, and to carry out a full observing programme.

Mr F. J. Sellers' Observatory, Muswell Hill, London

During 1953 sporadic observations only have been made and no regular records kept. This has been due partly to solar inactivity and dearth of notable incidents and partly to the observer's absence in hospital.

In 1954, when solar activity is likely to increase, it is hoped and expected that regular and systematic observation will be resumed and adequate records kept.

Dr W. H. Steavenson's Observatory, Cambridge

The 30-inch reflector has been used chiefly for photometric observations of old novae. The results obtained in the years 1950, 1951 and 1952 have been communicated to the Society.

Photometric observations of the two outer satellites of Uranus have been continued.

Some physical observations of comets have been made during the year.

Mr H. Wildey's Observatory, Hampstead, London

The 20½-inch reflector has been used for comet searches, and for observations of Jupiter and the Moon.

Several visitors have been entertained by the showing of objects of general interest.

Dr H. P. Wilkins' Observatory, Bexleyheath, Kent

The 15¼-inch reflector has been used for lunar and planetary observations, supplemented by observations with the 33-inch refractor at Meudon during April and with the 25-inch Newall refractor and Dr W. H. Steavenson's 30-inch reflector at Cambridge during September. The results of these observations have appeared as papers published in the *Journal of the British Astronomical Association*, the Spanish periodical *Urania* and the American publication *The Strolling Astronomer.*

Numerous visits were paid by members of the British Astronomical Association Lunar Section and the general public, when the Moon, Jupiter and Saturn have been exhibited. For observation by and for the instruction of visitors a 3½-inch refractor has been acquired.

Attention has been directed to the charting of the most minute lunar details which, after confirmation, have been inserted on the latest copies of the 300-inch lunar map.

REPORTS ON THE PROGRESS OF ASTRONOMY

STANDARD MAGNITUDES

A. W. J. Cousins and R. H. Stoy

The last Council Note (1) to touch on this subject was that on "Photographic Magnitudes" written by Professor Chapman in 1913. The photographic method was by that time almost fully developed; its possibilities were realized but many of the difficulties were not then apparent. Probable errors of $\pm 0^{m}{\cdot}1$ were easily achieved and a standard sequence extending as far as the twenty-first magnitude had been set up at the North Pole. It is more the purpose of this note to survey the present position than to summarize the development of astronomical photometry over the past forty years and to trace how the high hopes of 1913 for the accuracy of the photographic method and the utility of the North Polar Sequence were never quite fulfilled. A good historical account of this development, complete with references, has been compiled by Dr H. Weaver (2). The gradual evolution of the Polar Sequence itself can be followed in the series of reports prepared by Dr Seares (3) for Commission 25 of the International Astronomical Union. The last report to this Commission (4), drawn up by Professors Greaves and Redman, provides an excellent summary of the whole problem of standard magnitudes as it was three years ago. Since then several important papers bearing on this problem have been published, and the sensitivity of the photoelectric method has been extended to beyond the photographic limit by Baum and his associates at Mount Palomar (5).

General considerations.—"A stellar magnitude," says Dr Seares in an article (6) which should be compulsory reading for all astronomers, "is the measuring stick with which we sound the depths of space. Upon this unit, in some way or other, depend our distances of all the more remote objects in the heavens and, indeed, the dimensions of the universe itself, as far as we know it." Unfortunately magnitudes, though simple in concept, proved to be remarkably difficult to measure in practice. Part of this difficulty was technical and part was due to an incomplete understanding of what was being measured, so that different observers did not always measure the same thing.

The technical difficulties have now been very largely overcome by the introduction of efficient multiplier tubes and improved methods of amplification and recording. The observer is no longer handicapped by low sensitivity, at any rate not in the more usual spectral ranges, so that a precision of $\pm 0^{m}{\cdot}01$ can be relatively easily attained in general photometric programmes. The limiting factor is now usually the sky both as regards the faintness of the stars that can be measured and the accuracy with which these measures can be made.

Besides their importance as distance indicators, magnitudes can be used to obtain colour indices. These were originally derived from the differences between two magnitudes and this is still usually the case when the observations are made photographically. In the case of photoelectric observations, however, colour indices are measured directly and with much less trouble. The corresponding magnitudes are derived only if required. It was early recognized that these colour indices gave a convenient numerical estimate of the colour of the

stars and that they were strongly correlated with other properties such as the spectral type and gradient. They were in fact useful parameters connected with the physical state of the stars, and, in addition, were very convenient for reducing observed magnitudes to a standard system.

Because of the great extension in the spectral range to which photographic plates and photocells can be made sensitive, a large variety of magnitudes and colour indices can now be measured. This has given an added importance to colour indices, since by suitable selection of the colours observed they can be made to give even more information about the physical state of the individual stars. This has been achieved by studying the correlation between such colour indices and the results of spectral and spectrophotometric studies of a selection of the brighter stars. Thus integral photometry, though it can never be a complete substitute for detailed spectrophotometric study, has become very useful in providing convenient numerical data of a similar kind in a way that can be extended quickly to a large number of stars, including those which are too faint for any detailed study to be made.

In an attempt to achieve easy interpretation of the physical meaning of a magnitude some workers have concentrated their attention on monochromatic and narrow-band magnitudes. Such magnitudes are wasteful of light and can be determined only for the brighter stars. They are not so characteristic of the star's radiation as a whole as are wide-band magnitudes and are more subject to the influence of individual spectral lines. It is precisely this sensitivity to individual spectral lines and line blends that has been examined by Strömgren (7) in order to establish a method of determining spectral types by the use of interference filters.

Different systems of magnitudes and colours may well give equivalent information about the stars, but as the normal colours corrresponding to the various spectral types, the colour excess, total interstellar absorption, etc. all depend on the colour system chosen, much effort will be wasted if the work of one observer cannot be compared with that of another. It is therefore of fundamental importance to consider the conditions under which this can be done without a sensible loss of accuracy and which colour system will be most suitable for adoption as standard.

On the convertibility of magnitudes and colours.—If a star radiated precisely as a black body and if space were completely transparent, the radiation that reached the Earth could be uniquely defined by two parameters. Thus the measure of its magnitude and colour on any one system could be unambiguously transformed to a measure on any other. Stars do not radiate like black bodies and space is not completely transparent. It is an observed fact, however, that over a considerable range of wave-lengths (approximately 4000 A–7000 A for early types, 4600 A–7000 A for late types) stars do radiate sufficiently like black bodies for their radiation to be fairly well described by a magnitude and a colour index. For this same range of wave-length the interstellar absorption varies approximately as $1/\lambda$, so that the observed energy distribution of a reddened star is still approximately that of a normal star but at a lower temperature. Colour indices determined from radiation within this range correlate approximately linearly with one another, as they would if the stars were perfect radiators.

A colour index determined by comparing radiation from within this " black body range " of wave-lengths with radiation from outside it can give further

information. In the case of early-type stars the ultra-violet region of the spectrum has been found to be particularly important. U–B colour indices* do not show the same steady progression with spectral type from O to K as do B–V colour indices. Because of the hydrogen absorption, the near ultra-violet is actually weaker relative to blue light in main sequence A-type stars than it is in the stars of type F, so that the relation between U–B and B–V is not linear but shows a very marked " hydrogen dip ". For giant stars this relation is more nearly linear. Any blue magnitude system that includes light of wave-lengths shorter than 3800 A will be affected to some extent by this " hydrogen dip " and absolute magnitude effect, so that the transformation of one such magnitude system to another containing either no ultra-violet light or a different proportion of it will be non-linear and, if stars of several luminosity classes are present, multi-valued. This has been very convincingly demonstrated by Dr Harold Johnson (**8**).

Barbier and Chalonge (**9**) and Stebbins and Whitford (**10**) have shown that interstellar absorption does not vary strictly as $1/\lambda$, especially in the ultra-violet and the far infra-red. The apparent energy distribution in the spectrum of a reddened star therefore differs from that of a normal star, so that relations between magnitude systems that have been found from normal stars cannot be applied indiscriminately to reddened stars, especially if the colour systems of the magnitudes are widely different (**11**). The effect of reddening on the U–B, B–V (or similar) diagram is to displace it in both coordinates but not to change its essential characteristics. If such a diagram is plotted for a star cluster, it is possible to identify the stellar types from the shape of the resulting curve and to measure the amount of reddening by the displacement of this curve from its normal position. Both Becker (**12**) and Johnson and Morgan (**13**) have shown that it is possible by choosing a/b according to the law of reddening to find a function of the type $a(U\text{–}B) - b(B\text{–}V)$ which is independent of the amount of reddening and which can, with certain limitations, be used to identify the types of individual stars.

The selective character of interstellar absorption gives a special importance to work in the red and infra-red since the space penetration in these colours is very much better than in normal photographic light. These two colour ranges are also very useful in the study of red stars.

General considerations, together with the fact that stellar spectra are not continuous but are crossed by absorption lines and, in some cases, also by emission lines, suggest that there must be a limit to the accuracy with which magnitudes can be converted from one system to another. To find what this limit is and how it varies with circumstances we must turn to actual observations.

Magnitudes sufficiently well determined for such an investigation are available for the stars of the North Polar Sequence, a number of the brighter clusters, a few bright stars and for stars in the E regions at -45° which have been intensively observed in South Africa. These data are sufficient for a number of generalizations to be made. For wide-band blue and yellow magnitudes conversion from one system to another is fairly simple provided a measure of the colour is available for every star and if there are no complications due to ultra-violet light. For several of the series of E region observations the mutual external standard error when one series of magnitudes is converted to another does not exceed $\pm 0^m{\cdot}01$, even though the blue magnitudes do include a small fraction of light to the violet

* U is used to denote an ultra-violet, B a blue and V a visual magnitude.

of 3800 A. In the case of the six series of observations of the polar stars from which Redman (4) derived the " Interim " magnitudes for the Polar Sequence, the external standard errors are greater than $\pm 0^{m}\cdot 02$, but these magnitudes refer to a rather unusual selection of reddened stars and the requisite transformations are probably not linear as was assumed by Redman. For the conversion of the Cape Fabry photographic magnitudes and photoelectric colours to the Johnson and Morgan photoelectric B, V system for a number of bright stars observed in common, the mutual external standard error does not greatly exceed $\pm 0^{m}\cdot 01$ and similarly small external errors are found for observations of stars in clusters. In most cases, however, the mutual external error exceeds the internal error by an appreciable amount and there are usually a few exceptional stars for which the difference in the two magnitude determinations considerably exceeds what would be expected from the general run of the internal and external errors. This is particularly the case when photographically determined in-focus magnitudes are compared with one another or with magnitudes determined photoelectrically or by the Fabry method. Though some of these discrepancies may be due to variability, most must be attributed to other causes, such as peculiarities in the spectra of the individual stars.

For a number of the bright stars it is possible to compare wide-band magnitudes and colours with the monochromatic magnitudes and gradients determined at Canberra and Greenwich. Here, the external errors of the comparisons are very much larger and the number of " exceptional " stars greater. At present there are too few independent determinations of ultra-violet, red and infra-red magnitudes available for it to be possible to say much about their convertability from one system to another.

The essential properties of a standard system.—For a system of standard stars to be adequate it must be comprehensive, accurate and convenient in use. It is also most desirable that the magnitudes themselves should be so defined that their physical meaning can be interpreted.

To be comprehensive, the selection of stars which are to define the standard system must be carefully made so as to include examples of most spectral types, luminosity classes and differing degrees of reddening. Such a wide variety of stars is not to be found in any one region of the sky, so that we must accept the fact that our standard stars will be scattered over the sky. With the development of photometric techniques by which stars are observed individually, this is not the handicap it would have been when most observing was done by in-focus photographic methods. The ease with which it is now possible to establish accurate Pogson scales simplifies the problem, for the standard stars have only to define the colour system and the zero point.

To be completely adequate, the number of colour ranges in which the standard stars have to be observed must be such that it is possible by a combination of them to reproduce, within tolerable limits, the colour system adopted by any particular observer. This must not be taken to imply that *all* stars should be observed in so great a variety of colours. The visual observer, the compiler of catalogues, the statistician may well continue to be interested in one colour range only, while two colours seem to be sufficient for many purposes. Whatever official decision is taken about standard colour ranges, observers will, in practice, continue to use the colours that appear most suitable for their particular problem and convenient for their apparatus.

The standard system must be accurate. With modern techniques it is easy to ensure that the scale is sufficiently accurate. In none of the series of modern photoelectric or Fabry magnitudes that we have examined has the scale been in serious question. Constancy of zero point over the sky is not so easily achieved, but with patience and care the zero point can be tranferred from one part of the sky to another with an error not exceeding a few thousandths of a magnitude. Colour, being conventional, has to be defined by the standard stars themselves.

To meet modern requirements the internal accuracy of the magnitudes which define the system should be at least as good as $\pm 0{\cdot}^{m}01$ and possibly even $\pm 0^{m}{\cdot}005$. Magnitudes and colours are rarely required as accurately as this, but there is no reason to be content with standard magnitudes that are intrinsically less accurate than some of those they are intended to standardize. In the few cases where greater accuracy is required, e.g. the photometry of variable stars, the problem is usually a differential one and the question of standardization of secondary importance. Owing to the impossibility of keeping the conditions of observation absolutely constant, so that small errors inherent in converting observed magnitudes to the standard system are inevitably introduced, and the possibility of small variations in the standard stars, it is not worth pressing the accuracy of the magnitudes of the individual stars much beyond $0^{m}{\cdot}01$. More stars with magnitudes measured to this accuracy will define a standard system better than will fewer stars with magnitudes of higher accuracy.

The standard system must be convenient in use, otherwise it will be ignored in practice, as the Polar Sequence was for many years (**14**). Convenience in use implies accessibility, availability in a form that is easy to use and the choice of colour ranges that suit practical needs. These needs will differ from time to time. Photoelectric photometry has certainly displaced photographic methods for fundamental work but the latter's phase of usefulness is by no means over. Though its inherent accuracy is not so high, it is still extremely useful for observing many stars at once and for work in dense star fields. The advent of the Schmidt telescope and the development of work in the near infra-red have, in fact, given the photographic plate a new importance in astronomy. Moreover, even when photographs are not taken specially to determine magnitudes, there are still innumerable cases where it is important to know the magnitudes of the stars whose images appear on them. For example, in the determination of the proper motions of faint stars by photography, it is necessary to know the magnitudes of the comparison stars so that the appropriate statistical corrections may be applied. Very many more stars are needed to standardize photographic observations than photoelectric, but as the inherent accuracy of the observations is not high, the accuracy requirements for the standards are not so stringent. The standards used for photographic work must be grouped together. While this is not necessary for photoelectric work, it is a great convenience for the observer who wishes to check his zero point and colour system. A number of areas containing " working standards " are therefore required when the standard system is defined by the magnitudes and colours of individual stars scattered round the sky. The greater the number of these standard areas, the greater the accessibility of the system, but the more extensive will be the work necessary to establish it.

Some indication of the potentialities of the various available colour ranges is provided by the six-colour work of Stebbins and Whitford (**15**). For several

years Becker (**16**) has used with considerable success colour ranges centred at 3700 A, 4700 A and 6400 A. These colours are convenient for photography but not for the more sensitive photomultipliers available at present. The most important colour ranges appear to be the ultra-violet, blue, visual and near infra-red. The usual photographic and photovisual systems are easily reproducible with existing photomultiplier tubes. They give an adequate base line for the determination of a significant colour index without sacrificing too much light. The objection to the ordinary photographic magnitude is that it usually contains light to the violet of 3800 A in an undefined proportion, depending on the type of instrument with which it was obtained. As Baade (**17**) pointed out many years ago, this troublesome ultra-violet light can be eliminated by a suitable filter such as Schott's GG 13. If this is done, photographic and photoelectric magnitudes obtained through appropriate filters should be easily convertible one to another and to an adopted standard blue system.

Johnson and Morgan's (**18**) *B* magnitudes provide what appears to be an acceptable system for present-day needs. The *P* system (**19**) adopted by a number of American astronomers is nearer the old IPg system but suffers from the same disadvantage of containing an unspecified quantity of ultra-violet light and of being defined for only a few reddened stars at the Pole. There is no reason, however, why this system should not be more adequately defined, e.g. as a linear conversion of the Johnson and Morgan *B*, *V* system that gives the best fit to the old IPg. The 1953 SPg system (**20**) corresponds closely to a photographic magnitude obtained with a refractor. It contains some light to the violet of 3800 A but not sufficient to be inconvenient in practice. Its colour system is close to that of IPg, but there is a difference in zero point of $0^{m}\cdot05$.

In the yellow region Johnson and Morgan's *V* system, which may be equated with IPv, seems to be acceptable. One possible objection to it is that photographic observations in this general region are more conveniently made slightly to the red of it where the plates are more sensitive. However, magnitudes obtained by extrapolation from the *B*, *V* system or by interpolation between *V* and a red system are sufficiently accurate for standardizing such photographic observations. SPv lies slightly to the red of *V* and, suitably transformed, has been used for reducing photographic observations made on panchromatic plates behind a yellow filter. It has proved adequate for this purpose, but in the case of precision Fabry observations there were a number of significant but isolated differences between the observed and standard magnitudes for stars of type K5 and later. This may indicate the desirability of having red magnitudes available for use when late-type stars are to be observed.

Photometric observations in the ultra-violet and infra-red ranges are still in the initial stages of development. For work in the ultra-violet a filter with a fairly sharp cut-off towards the red at about 3800 A is required (e.g. Corning 9863 or Ilford 828). On the short wave-length side the cut-off will usually be determined by the transmission of the objective, the reflectivity of the mirror or by the atmospheric transmission. In the infra-red range the choice of wave-band is circumscribed by the sensitivities of the available plates and photocells and by the atmospheric absorption bands.

It is desirable that the magnitudes of the standard stars should be precisely defined so that their physical meaning can be interpreted in terms of the metre,

gram and second. It is quite possible to define a magnitude system by specifying the spectral response of the standard receiver, but it is not possible to achieve a standard system merely by specifying the apparatus with which the magnitudes and colours are to be observed. Telescopes differ in their transmissions, photographic plates and photocathodes, even when of the same type, differ in colour sensitivity and so on. Thus a magnitude system defined theoretically must be translated into practice by means of specified magnitudes for a suitable selection of stars. There are presumably no better theoretical objections to this procedure than there are to defining a metre as the distance between two marks on a platinum bar instead of one forty-millionth of the Earth's circumference, or a kilogram as the mass of a certain lump of platinum instead of the mass of a cubic decimetre of water. As, however, it cannot be assumed that any particular star is strictly constant, the magnitude system has to be defined in terms of a sufficiently large number of stars for the effect of small variations of individual stars to be negligible.

When once one system of magnitudes has been interpreted physically, it should be possible to deduce the physical meaning of any other system from the nature of the relations between the two systems. Many workers do publish the spectral response curves of their filter and cell combinations as determined in the laboratory, but few have, as yet, attempted to include the effect of the optical train of the telescope. The setting up of magnitudes that can be used to interpret the standard system is not likely to be either a short or an easy task, but it is one well worth doing. Concepts such as that of an "effective wave-length" have a certain theoretical interest but they are inadequate in practice for interpreting magnitude systems because stars are not perfect radiators. To reconcile theoretical ideas with observation to the accuracy achieved by modern observations of wide-band magnitudes it is necessary to consider both the response curve of the receiver and the actual energy curves of the stars in question (**21**).

The choice of practical standards.—Johnson and Morgan (**18**) have recently provided the framework of what appears to be an adequate and acceptable system of standard magnitudes and colours for a three-colour photometry with effective wave-lengths at about 3500 A (U), 4300 A (B) and 5500 A (V). This system is rendered the more valuable because the spectral types of most of the standard stars have been accurately classified on the revised system of the Yerkes Spectral Atlas. Moreover, many of the same stars have also been observed in the red and infra-red at effective wave-lengths of about 7000 A (R) and 8250 A (I) by Kron and his associates (**22**), and many more are to be so observed by Dr Hardie of the Lowell Observatory.

The standard stars have been selected to represent adequately all of the regions of the Hertzsprung–Russell diagram. Main-sequence stars from O to M, yellow giants from G0 to M2, little reddened supergiants from B0 to M2, white dwarfs, moderately and heavily reddened O and B stars have all been included in the list. The stars are scattered over the sky and a number of them, to satisfy the condition of little reddening, are very bright. Unfortunately some of the stars in this list are fairly far north and are not accessible from the Southern Hemisphere. This is a defect which can be easily amended. The Johnson–Morgan system is a partial return to the pre-1922 definition of the International system. V appears to coincide with IPv, while the zero point

of the *UBV* colour system has been set by making $U-B$ and $B-V$ both equal to zero for the mean of six bright stars of class A0 V on the MK system, while for K0 III stars, $B-V=+1\cdot01$.

The adoption of a new standard system does not mean that the work that has been done in the past using the Polar Sequence for its standards cannot be used. Any such work can be reduced to the new system without any sensible loss of accuracy except that inherent in any photographic magnitudes that contain light to the violet of 3800 A. For most of the pre-photoelectric observations this ambiguity is considerably less than the inherent errors of observation.

It remains, for the convenience of observers, to set up a number of standard regions enshrining this system. So far the regions of the Pleiades, Praesepe and IC 4665 have been observed for this purpose. These clusters, though useful for some purposes, do not form good standard regions for photographic work. This is partly because of the relationship that exists between the magnitude and colour of the cluster stars themselves and partly because of the high concentration of stars. A reasonable compromise between accessibility, convenience in use and the work necessary to establish the standard system seems to be provided by the recommendation made by the International Astronomical Union at the 1952 Meeting, viz. that special preference should be given to six areas at $+15°$ (S.A. 68, C 2, C 4, C 7, S.A. 85 and S.A. 89) and to the nine E regions at $-45°$.

It is probably not practical to set up immediately in all the standard areas sequences on the Johnson–Morgan system adequate for all purposes. The first step is to coordinate all the work that has already been done on these areas and to transform it to the new system. The task of strengthening these data and rendering them suitable for particular needs can best be left to the initiative of individual workers, or groups of workers, to be done as the need arises. For some special photographic investigations, e.g. of the Magellanic Clouds, parts of the Milky Way, etc., it will probably prove more convenient to set up, presumably by photoelectric means, local sequences designed for that special purpose than to attempt transfers from one of the more general standard areas.

It is not necessary to observe in the standard colours, but it is advisable to observe as close to them as is convenient for the problem in hand. The main point is, as it has always been, that astronomers doing photometric work should either standardize their results or, at the very least, provide the means by which they can be standardized. The widespread use of photoelectric photometry has made this very much easier than in the days when photography was the principal method of observation.

The 1953 S System (**20**) provides a standard system for two-colour photometry in the Southern Hemisphere. The standards include at present from 60 to 100 stars in each of the nine E regions at $-45°$. Stars between the second and sixteenth magnitude are included, but the system itself can only be considered as defined as far as the eleventh magnitude. The internal errors of this system appear to be small. It was designed originally for photographic work and should be particularly useful for this purpose. Work on the S System and on its relation to the Johnson–Morgan *B*, *V* system is still in progress. The best *linear* relation between the two systems available at present is

$$B = \mathrm{SPg} - 0\cdot07\ \mathrm{SCI} + 0\cdot20$$

$$V = \mathrm{SPv} + 0\cdot08\ \mathrm{SCI} - 0\cdot06$$

$$B - V = 0\cdot85\ \mathrm{SCI} + 0\cdot26$$

but these must not be taken as definitive, especially where blue stars are concerned. The relation with IPg and ICI as far as these are defined by the magnitudes of stars in the Mount Wilson North Polar Catalogue (**14**) is

$$\mathrm{IPg} = \mathrm{SPg} + 0{\cdot}01\ \mathrm{SCI} + 0{\cdot}05$$
$$\mathrm{ICI} = 0{\cdot}93\ \mathrm{SCI} + 0{\cdot}11$$

In some ways the magnitude position in 1913 seemed clearer than it does today. Then there was a single Polar Sequence to the system of which all observed magnitudes were to be reduced. Today the Polar Sequence is quite inadequate, and with photometry developing as rapidly as it is, it is premature to introduce new absolute standards. Instead we may try to agree on a number of standard stars to define our magnitude system and a number of standard areas to make this system convenient in use. There is no question of laying down the magnitudes of these standard stars once and for all. As techniques improve and new methods are introduced, fresh magnitudes for them will be found. The previous work that has been done using these stars as a reference system will not be wasted, but through them can be firmly built into the steadily growing edifice of knowledge.

References

(1) S. Chapman, *M.N.*, **73**, 291, 1913.
(2) H. Weaver, *Pop. Ast.*, **54**, 211, 287, 339, 389, 451, 504, 1946.
(3) F. H. Seares, *Trans. I.A.U.*, **1**, 69, 1922; **2**, 83, 1925; **4**, 136, 1933; **6**, 215, 1939.
(4) *Trans. I.A.U.*, **8**, 355, 1952.
(5) W. A. Baum, *A.J.*, **58**, 211, 1953.
(6) F. H. Seares, *P.A.S.P.*, **50**, 5, 1938.
(7) B. Strömgren, *A.J.*, **56**, 142, 1952.
(8) H. L. Johnson, *Ap. J.*, **116**, 272, 1952.
(9) D. Barbier and D. Chalonge, *Ann. d'Astrophys.*, **4**, 30, 1941.
(10) J. Stebbins and A. E. Whitford, *Ap. J.*, **98**, 20, 1943.
(11) W. W. Morgan, D. L. Harris and H. L. Johnson, *Ap. J.*, **118**, 92, 1953.
(12) W. Becker, *Ap. J.*, **107**, 278, 1948.
(13) H. L. Johnson and W. W. Morgan, *Ap. J.*, **117**, 341, 1953.
(14) F. H. Seares, F. E. Ross and M. C. Joyner, *Mt. Wilson Papers*, **6**, 1, 1941.
(15) J. Stebbins and A. E. Whitford, *Ap. J.*, **102**, 318, 1945.
(16) W. Becker, *Mitteilungen der Göttinger Sternwarte*, No. 79, 1946.
(17) W. Baade, *Trans. I.A.U.*, **6**, 216, 1939.
(18) H. L. Johnson and W. W. Morgan, *Ap. J.*, **117**, 313, 1953.
(19) H. L. Johnson and W. W. Morgan, *Ap. J.*, **114**, 526, 1951.
(20) *Cape Mimeogram* No. 3, 1953.
(21) S. Ninger-Kosibowa, *Cont. from Wroclaw Obs.*, No. 8, 1952.
(22) G. E. Kron and J. Lynn Smith, *Ap. J.*, **113**, 324, 1951. G. E. Kron, H. S. White and S. C. B. Gascoigne, *Ap. J.*, **118**, 502, 1953.

MINOR PLANETS

This report for the years 1952 and 1953 succeeds the last one given in *M.N.*, **112**, 332. In general, the work has levelled off to what might now be considered as the normal rate. There were 142 and 152 MPC's issued in these years, and the number of provisional designations was 356 and 453. The number of improved orbits was 55 and 25. The lower value in the latter case doubtless reflects the termination of punched card operations for the computation of special perturbations at the Cincinnati Observatory in 1951. At the present time the writer is preparing a more elaborate programme for large electronic computers, with the possibility of much higher accuracy. An upsurge in this activity is to be expected when it is completed.

The preparation of the Minor Planet Circulars for publication continues under the immediate supervision of Dr E. Rabe. The translation of and supplement to the annual volume of Minor Planet ephemerides published at Leningrad has been prepared each year by Dr P. Musen. There has been a widening appreciation of the benefits of the cooperative plan under which the Cincinnati Observatory computes perturbations for use by other workers in the improvement of orbits. This augurs well for the future. In other respects the work continues in a satisfactory manner.

PAUL HERGET.

SOLAR ACTIVITY

Sunspots.—By the end of 1953, if not somewhat earlier, the sunspot cycle may be said to have entered its minimum phase. However, the epoch of minimum sunspot frequency had almost certainly not then been reached.

The first fully confirmed high-latitude sunspot of the new cycle was recorded on August 13 in the unusually high latitude of 52° north (*P.A.S.P.* **65**, 256, 1953). This spot could have lasted only for a few hours, and it is not improbable that a similar one occurred earlier on July 23 in south latitude 27° (*The Observatory*, **73**, 213, 1953). A patch of faculae in south latitude 53° on June 8 : small patches (*plages*) of calcium flocculi in latitudes N. 41° and S. 43° in May, and coronal emissions (5303 A and 6374 A) reported from Climax in latitudes around 30° from 1952 September may all be taken as the immediate precursors of solar minimum. The observation of weak magnetic fields in high solar latitudes by the new technique developed by the Babcocks appears of interesting significance at this phase of the sunspot cycle (*M.N.*, **113**, 357, 1953; *P.A.S.P.*, **65**, 256, 1953).

Short-lived flecks of faculae are still of frequent occurrence in high latitudes from 60° to 80°.

The mean sunspot number for 1953 is 13; that for the last three months of the year being 3. The total number of spotless days exceeds 140, November contributing 25 and December 25. This total number compares with 240 days (range 157 to 310) as the average number of spotless days for the year of sunspot minimum over the last seven cycles.

Of the diminishing number of spots, only one, with its central meridian passage on April 28, exceeded in maximum area 500 millionths of the Sun's hemisphere, but it did so by a generous excess, raising the area on April 29 to 1100 millionths. Another spot (latitude N. 10°) with central meridian passage on August 17 fell just short of 500 area units.

Few solar flares were recorded during 1953. Probably the most important in Greenwich daylight hours was that on October 14, not directly observed at Herstmonceux owing to cloudy skies but recorded from its u.v. effects on the ionosphere as commencing at $09^{h}\ 52^{m}$ U.T. and rising to a maximum at $10^{h}\ 00^{m}$. This flare produced a synchronous fade-out, lasting 15–20 minutes, on radio channels in operation by Cable and Wireless Limited. A geomagnetic crochet was recorded at the time, at Hermanus, South Africa.

Although sunspots have been few, with periods of entire absence, geomagnetic activity has often been present in two M-region sequences of small recurrent storms. The first of these sequences—a legacy from 1952—died out in mid-May, but the second sequence took its place and was still in action, though much weakened, at the end of the year. The latter had a more uniform front than the first sequence on a time-pattern diagram representing recurrent onset times at intervals of nearly 27 days, as follows :—May 6, June 2, June 29, July 26, August 23, September 17, October 15, November 11 and December 10. The equivalent displacement in solar longitude of the second M-region from the first is about 225°. H. W. NEWTON.

Prominences.—The mean daily areas and numbers of calcium prominences at the limb as derived from photographs taken at Kodaikanal are given below :

	Area in square minutes					Number				
1953	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	0·90	0·92	0·78	1·04	1·82	3·63	3·43	3·17	3·89	7·06
July–Dec.	0·99	0·99	0·92	1·06	1·98	3·47	3·53	3·34	3·66	7·00
Whole year (weighted mean)	0·94	0·95	0·84	1·05	1·89	3·56	3·47	3·24	3·79	7·03

Compared with the previous year prominence activity as represented by areas shows a decrease of about 19 per cent while the numbers show a decrease of about 16 per cent.

The distribution of areas in 5° ranges of latitude shows maximum activity in the zone 35°–40° in both the hemispheres. There is a secondary maximum of activity between 20°–25° in the northern hemisphere and two secondary maxima between 10°–15° and 20°–25° in the southern hemisphere. There was very little activity beyond 45° in both the hemispheres. The east–west distribution of prominences showed that both areas and numbers were in excess on the west limb.

Doppler shifts of the H-alpha line observed in prominences and absorption markings with the prominence spectroscope and the spectroheliosope are given below :

	North	South	East	West	To red	To violet	Both ways	Total
Prominences	21	7	16	12	2	1	25	28
Dark markings	12	2	8	6	...	...	14	14

The heights of 13 prominences were measured in H-alpha, D_3 and H-beta lines with the prominence spectroscope. These were compared with the corresponding heights in the K line as obtained from the spectroheliograms. The average heights were:

K	H-alpha	D_3	H-beta
50″·1	47″·0	43″·1	40″·8

There were 6 occasions during the year when sudden disappearances of hydrogen absorption markings on the disk or of prominences on the limb were observed.

One metallic prominence was observed during the year.

An eruptive prominence was observed on the N.E. limb between $04^h\ 30^m$ and $05^h\ 45^m$ U.T. on February 26. The prominence reached a maximum height of 260″, after which it disintegrated. Maximum Doppler shifts of about 6 A to red were observed in some parts of the prominence. An interesting feature associated with this eruptive prominence was a synchronous radio noise burst recorded by the 100 Mc/s radio telescope of this observatory (*Nature*, **132,** 446).

The mean daily areas and numbers of hydrogen absorption markings on the disk as obtained from Kodaikanal records are given below :

	Area (in millionths of the Sun's visible hemisphere) uncorrected for foreshortening					Number				
1953	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	621·7	583·2	589·0	615·9	1204·9	5·96	5·73	5·86	5·83	11·69
July–Dec.	686·3	351·7	510·2	527·8	1038·0	7·50	4·13	5·61	6·02	11·63
Whole year (weighted mean)	650·6	483·9	555·7	578·8	1134·5	6·64	5·04	5·76	5·92	11·68

Compared with the previous year's values both the areas and numbers show a decrease of 38 per cent.

The distribution of areas in 5° ranges of latitude shows two peaks of activity in both the hemispheres, between 20°–25° and 40°–45° in the northern hemisphere and between 5°–10° and 35°–40° in the southern hemisphere. There was little activity of dark markings beyond latitude 50°. Both areas and numbers of H-alpha dark markings show western excess. A. K. DAS.

DOUBLE STARS

New pairs.—Finsen (*M.N.A.S.S.A.*, **12,** 34 and 86 ; *The Observatory*, **73,** 165) gives new pairs discovered with the interferometer, Rossiter (*A.J.*, **58,** 29) his seventh and last list of new southern double stars (Rst 5492–5560).

Measures.—Measures of double stars are given by Couteau (*J.O.*, **35,** 181; **36,** 37 and 46), Donner (*A.J.*, **58,** 164), Finsen (*U.O.C.*, **6,** 170), Jonckheere (*J.O.*, **36,** 49), Rabe (*Ast. Abh.*, **12,** No. 3), Schmeidler (*M.N.*, **112,** 676), van den Bos (*U.O.C.*, **6,** 185) and Wilson (*A.J.*, **57,** 248).

Orbits:

Double Star	*P*	*e*	*a*	Computer	Reference
ADS 784	83·9	0·24	0·25	Kent	*A.J.*, **57,** 233
,, 1223	144	0·96	0·919	van den Bos	*U.O.C.*, **6,** 209
,, 1538	155	0·75	1·18	Palacios	*Urania*, **37,** 201
,, 1709	143·3	0·249	0·943	Gonzalez	*Urania*, **38,** 7
,, 1833	264·3	0·42	0·46	Baize	*J.O.*, **36,** 1
,, 3711	162·8	0·32	1·04	Baize	*J.O.*, **36,** 1
,, 5559	3190	0·485	9·550	Hopmann	*Mitt. Wien*, **6,** 7
,, 6650 AB	59·7	0·32	0·88	Gasteyer	*A.J.*, **58,** 39
CD, C	17·8	0·11	0·20		
AB, CD	1150	0·26	7·5		

Double Star		*P*	*e*	*a*	Computer	Reference
ADS	6825	40·0	0·180	0·193	van den Bos	*U.O.C.*, **6**, 211
,,	6828	53·0	0·450	0·321	van den Bos	*U.O.C.*, **6**, 211
,,	7082	43·5	0·76	0·55	Baize	*J.O.*, **36**, 1
,,	7307	220·1	0·610	1·46	Güntzel-Lingner	*A.N.*, **281**, 79
,,	8148	192·0	0·54	2·00	Güntzel-Lingner	*A.N.*, **281**, 133
,,	9185	36·0	0·90	0·28	Baize	*J.O.*, **36**, 1
,,	9380	220·5	0·671	0·947	Pensado	*Un. Madrid P.*, 13
,,	9392	442·6	0·514	0·910	Pensado	*Un. Madrid P.*, 10
,,	9757	91·0	0·42	0·74	Baize	*J.O.*, **36**, 1
,,	10075	236·07	0·767	2·234	Siegrist	*Un. Madrid P.*, 11
,,	10421	106	0·580	0·351	van den Bos	*U.O.C.*, **6**, 215
,,	11046	87·8	0·499	4·556	Geffers	*Veröff. Bonn*, No. 39
	(perturb.)	9·89		0·014		
,,	11468	85·5	0·165	0·190	Wierzbinski	*Poznan O. Repr.*, No. 27
,,	11520	12·18	0·260	0·196	van den Bos	*U.O.C.*, **6**, 216
,,	11632	∞	1·0	(16·604)	Wieth-Knudsen	*Ann. Lund*, 12
,,	11897	250	0·889	0·537	Pensado	*Urania*, **37**, 140
,,	12126	124·2	0·715	0·247	van den Bos	*U.O.C.*, **6**, 217
,,	13169	122·0	0·18	0·36	Baize	*J.O.*, **36**, 1
,,	14775	77·33	0·220	0·180	van den Bos	*U.O.C.*, **6**, 218
,,	15972	44·6	0·41	2·412	Lippincott	*A.J.*, **58**, 135
,,	16708	63·16	0·120	0·420	van den Bos	*U.O.C.*, **6**, 214
(pos. 1900) h m	°					
2 34·7	−12	1·59	0·27	0·117	Finsen	*M.N.A.S.S.A.*, **12**, 18
3 29·9	−31	19·40	0·30	0·236	van den Bos	*U.O.C.*, **6**, 209
4 11·1	−46	25·00	0·450	0·222	van den Bos	*U.O.C.*, **6**, 210
8 35·5	−36	54·0	0·80	0·477	van den Bos	*U.O.C.*, **6**, 212
9 37·6	−57	10·00	0·300	0·161	van den Bos	*U.O.C.*, **6**, 213
12 51·0	−47	294	0·872	0·695	van den Bos	*U.O.C.*, **6**, 214
16 50·1	− 8	1·714	0·045	0·201	Wieth-Knudsen	*Ann. Lund*, 12

Güntzel–Lingner (*A.N.*, **281**, 79) gives graphical devices for the approximate determination of the orbit of a visual binary, McLeod (*A.J.*, **57**, 234) a method of computing an orbit perpendicular to the plane of the sky, Muller (*J.O.*, **36**, 61) a catalogue of 304 ephemerides (that for Sirius is erroneous), Pajares (*Ac. Madrid*, **46**, 307) discusses a problem in the determination of double star orbits, Palacios (*Urania*, **37**, 201) gives a method of correcting a double star orbit, van den Bos (*U.O.C.*, **6**, 214) a note on the orbit of *p* Velorum and Wieth–Knudsen (*Ann. Lund*, 12) orbit determination of a visual binary of small eccentricity and inclination, and adaptation of Thiele's method to the parabolic and quasi-parabolic case.

Miscellaneous.—Agekian (*Ast. Zhurnal*, **29**, No. 2, 219) writes on the coplanarity of the orbits of triple stars, Johnson (*Ap.J.*, **117**, 361) gives photoelectric observations of visual double stars, Jonckheere and Couteau (*J.O.*, **36**, 44) an important correction to ADS, Lourens (*M.N.A.S.S.A.*, **12**, 64) a note on a fictitious double star in the Cape Zone Catalogues, Muller (*J.O.*, **35**, 177; *Ann. Strasbourg*, **5**, No. 4; *Ann. d'Astroph.*, **15**, 79) magnitudes and colours of double stars, Struve (*P.A.S.P.*, **64**, 290) spectra of some visual double stars, van den Bos (*U.O.C.*, **6**, 183) a study of Finsen's interferometer measures, and van de Kamp and Damkoehler (*A.J.*, **58**, 21 and 25) the parallax and orbital motion of 61 Cygni and σ Coronae Borealis.

W. H. VAN DEN BOS.

COMETS (1953)

The year was another unspectacular one as regards comets, and only three reached even the eighth magnitude. Of fifteen comets observed, four were new discoveries, of which one had an orbit of short period, five were periodic ones recovered as predicted, and the remaining six were comets followed from previous years, including the two "annual" ones. Over the last eight years an average of five new comets were discovered every year, of which one in three has had an elliptical orbit of short period. Since the latter half of 1949, when the National Geographic Society Palomar Sky Survey was started with the 48-inch Schmidt camera at Mount Palomar, eight of the new comets have been found on routine plates taken for this project, that is about two a year.

During the year under review the annual comet Schwassmann-Wachmann (1) was under observation up to July, and had one of its outbursts in April, rising in brightness from 16^m on March 16 (Richter) to 13^m in mid-April (Van Biesbroeck). By July 4 it was down again to 18^m, a nearly stellar object (Jeffers). Oterma's comet was only observed a few times early in July, a nearly stellar object of seventeenth magnitude (Van Biesbroeck, Jeffers).

1950 b Minkowski was observed for the last time, by Van Biesbroeck with the 82-inch reflector at the McDonald Observatory, on January 18 of this year, a round coma about 20″ in diameter of eighteenth magnitude. It had been discovered on 1950 May 19, and the observations therefore cover an interval of thirty-two months.

1951 h, the periodic comet Comas Solá, continued to follow Vinter Hansen's ephemeris closely, both in position and brightness. It was of fourteenth magnitude in January (Boyer), with a good nucleus and a tail that was still a conspicuous feature (Van Biesbroeck). The last observations of it were obtained by Miss Roemer and Vasilevskis on July 3 at the Lick Observatory, and by Van Biesbroeck at the McDonald Observatory on July 4. It was then a slightly diffuse round object, 6″ in diameter, between 17^m and 18^m. The observations at this apparition have covered an interval of almost exactly two years.

1952 e Harrington did not come to perihelion till the beginning of the year. It reached its maximum brightness early in February, around $8^m{\cdot}0$, the coma being then moderately condensed, about 7′ in diameter, with a non-stellar nucleus of about twelfth magnitude (Beyer, A. Jones). By the beginning of May it had faded nearly to twelfth magnitude (A. Jones); and it was last observed, by Jorge Bobone and Angel Puch at Córdoba, on June 29·9, magnitude $13\frac{1}{2}$.

1952 f Mrkos too reached perihelion in January, and was then an object of between seventh and eighth magnitude, about 4′ in diameter but strongly condensed in the central 2′ (A. Jones, Philpott). It was followed till mid-February by southern observers before it was lost behind the Sun; but it was recorded again in July, at the Lick and McDonald Observatories, when it was of the eighteenth magnitude, and finally by L. E. Cunningham at Mt Wilson on September 5.

The dates of the last-known observations in 1953 of these comets of previous years are summarized in Table I.

TABLE I

Last-known observations of position of previous years' comets

Comet		Date	Mag.	Observer	Remarks
		1953			
1925 II	P/Schwassm. Wachm. (1)	July 4	18	Jeffers	Nearly stellar
1942 VII	P/Oterma	July 10	17	,,	,, ,,
1950 b	Minkowski	Jan. 18	19	Van Biesbroeck	Coma 20″
1951 h	P/Comas Sola′	July 4	17	,,	
1952 e	Harrington	June 29	$13\frac{1}{2}$	Bobone, Puch	
1952 f	Mrkos	Sept. 5	(19)	Cunningham	

1953 a, the first comet to be discovered this year, was found by Antonín Mrkos, in Pegasus near the border of Delphinus, during a routine search with Somet " Binar " binoculars (100 mm, ×25) at the Skalnaté Pleso Observatory on April 12·1; and was also found later the same day by the Japanese amateur astronomer, Minoru Honda, at Kurasiki, also with binoculars (100 mm, ×15). The comet appeared as a large diffuse object 10′×4′, of magnitude 9·0 (Honda). It brightened to $8^{m}\cdot5$ in May and was then generally described as round, or only slightly elongated, centrally fairly strongly condensed, about 4′ in diameter. Max Beyer and W. H. Steavenson, while observing it visually between May 10 and 13, noted also a stellar nucleus of thirteenth magnitude. The comet was followed till July, by which time it was getting near the Sun in the evening sky and had faded to about 12^{m}. It was recovered by Van Biesbroeck before dawn on September 13, a rather small very diffuse object of fifteenth magnitude, and was last recorded by Miss Elizabeth Roemer at Lick Observatory on the first day of the new year, a very faint image of nineteenth magnitude.

1953 b was the periodic comet Brooks (2) recovered, in the position predicted by T. A. Goodchild, by Miss Elizabeth Roemer and Hamilton M. Jeffers with the 36-inch Crossley reflector (*f*/5·8) at the Lick Observatory on June 18·4. The image was round, uncondensed, 10″ in diameter, of magnitude $18\frac{1}{2}$, containing a sharp nucleus. The sharpness of the central condensation or nucleus was remarked again by Van Biesbroeck, and by Jeffers, in July when they noted also a slender tail about 1′ long extending westwards. Even at perihelion in August the comet was never much brighter than about seventeenth magnitude, more than two magnitudes fainter than expected. It was still under observation, about 18^{m}, at the end of the year.

1953 c, comet Pons-Brooks, which has a period of 71 years, was recovered on June 20·4, within 25′ of the position predicted by Paul Herget, by Miss Elizabeth Roemer with the Crossley reflector of the Lick Observatory. The image showed a sharp nucleus with coma mostly on the south-west side, about 0′·3 in diameter, the total brightness being $17\frac{1}{2}^{m}$.

The comet soon gave evidence of considerable variations both in brightness and appearance, as it had done at its previous return in 1883–84. At times it showed a diffuse coma 1′ or 2′ in diameter, at others the light was condensed in a small, almost stellar disk. The changes seem sometimes to have been fairly rapid. For instance, on September 12·9 the comet was seen to have a coma

of diameter 1′ or 2′, 13^m to 14^m (Steavenson); and also on September 16·9 (Steavenson), September 28 (Van Biesbroeck) and on October 6·8, when it was $12^m \cdot 2$ (Beyer), a coma of $1\frac{1}{2}'$ or more was reported; whereas between these dates, on September 15 (Kresák), September 18·0 when it was $12^m \cdot 8$ (Merton) and October 3 (Kresák), its image was of stellar appearance.

The period just mentioned was one when the brightness had risen above that predicted. Generally speaking the observed magnitudes were below those predicted by N. T. Bobrovnikoff's formulae from the 1883–84 observations, sometimes by several magnitudes. A preliminary plot of the reported magnitudes shows considerable scattering, even among the observations of experienced observers, especially in December when the observations became more numerous. A possible explanation is that some considerable fluctuations took place in a matter of hours, as it seems happened in 1883–84.

There is evidence of three surges of brightness before the end of the year. The first took place during the last ten days or so of June, just after the comet had been found. The observed brightness rose from seventeenth magnitude to a maximum of 13^m on July 2 (Van Biesbroeck), after which the brightness fell back to 17^m or 18^m. A more gradual rise, of three or four magnitudes, took place in September, reaching about $12^m \cdot 2$ early in October (Beyer, Waterfield), after which the brightness again fell several magnitudes. Then there appears to have been a rather sudden surge upwards of several magnitudes in five or six days at the beginning of December, reaching 10^m on December 10 (Van Biesbroeck), from which, this time, there was a fall of only a magnitude or two.

At the end of the year, and early in the new year, the comet was reported as having a coma about $3\frac{1}{2}'$ in diameter, with a fourteenth magnitude nucleus, the total brightness being then around 11^m, the predicted value.

1953 d was the short period comet Reinmuth (2), recovered by G. van Biesbroeck on July 5·2, close to the position predicted by E. Rabe, with the 82-inch reflector at the McDonald Observatory. Its image showed a small nebulosity, only 5″ in diameter, of nineteenth magnitude. Two further plates were obtained by him on July 15, but Cunningham reported that on September 4, when the comet should have been a magnitude brighter, a plate taken with the 100-inch reflector at Mt Wilson failed to show it.

1953 e was discovered by Robert G. Harrington on a plate taken in Aquarius for the National Geographic Society Palomar Sky Survey with the 48-inch Schmidt camera on August 14·4. It was a diffuse object of fifteenth magnitude with some central condensation and a short tail. The orbit was found to be of short period (6·9 years). Observations by Van Biesbroeck on September 15 and 16, a few days before perihelion passage, described the comet as of sixteenth magnitude, with a centrally condensed coma 20″ in diameter, from which stretched a faint tail 3′ long in position angle 300°. The last reported observation was obtained by Miss Roemer at the Lick Observatory on December 10. The image was then nearly stellar, $18^m \cdot 8$.

1953 f, Encke's short-period comet, was recovered on September 3·4, while it was of twentieth magnitude, by Leland E. Cunningham with the 100-inch reflector at Mt Wilson. The comet was then still ten months from perihelion, the earliest it has ever been recovered. It was next photographed with the 100-inch by S. B. Nicholson on November 4, and was again under observation in the new year.

1953 g, discovered in Camelopardus by George O. Abell on October 15·4, was another comet found on plates taken for the sky survey with the 48-inch Schmidt at Mount Palomar. The image was of a diffuse object, 0′·6 in diameter markedly condensed to a nearly stellar centre, and had a tail 1′·5 long, the total brightness being estimated as 15^m. It passed almost exactly over the north pole of the Earth on November 20 at a distance of nearly three units from us. By the end of the year its brightness had increased to $12\frac{1}{2}^m$; and it was well observed in the new year.

1953 h, the last new comet of the year, was discovered in Cetus on December 3·8 by Mrs Ludmila Pajdušáková-Mrkosová, during routine sweeps with Somet binoculars (100 mm, ×25) at the Skalnaté Pleso Observatory. A photograph confirming it was immediately obtained by A. Paroubek and Miss R. Šášky with the 13-inch Maksutov camera there. The comet was a diffuse object of eleventh magnitude, having a feeble nucleus but otherwise without appreciable condensation, with a broad tail 2′ to 3′ long in position angle 40°. Other reports a few days later gave the length of the tail as about 10′ (Van Biesbroeck, Mitani).

The light of this comet failed to increase as expected as the comet approached perihelion (1954 January) and it was no better than 9^m at the end of the month. Although on December 29 Van Biesbroeck recorded the tail as 30′ long, he remarked the comet was disappointingly faint, about $10^m·5$. In the course of the next few days the comet became large and diffuse and faded out. Vasilevskis at the Lick Observatory took a photograph with the 20-inch astrograph on January 5 (1954) and found the comet had practically disappeared, there being but a faint image 7′×2′; and the last known observation, a visual one by Max Beyer later the same day, gave it as about tenth magnitude, very faint and large. Attempts to record it again, made by Van Biesbroeck on January 8 and by H. M. Jeffers on January 9 and 10, were unsuccessful and it was concluded that the comet was then fainter than 14^m.

1953 i, the periodic comet Finlay which had not been observed since 1926, was recovered, with the aid of a prediction by Rudolph Luss, by J. Churms on plates taken on December 7·8 and 8·8 with the Franklin Adams camera (10-inch, *f*/4·5) at the Union Observatory, Johannesburg. Its brightness was then about $13\frac{1}{2}^m$, but by December 29 it had increased to $10\frac{1}{2}^m$, and showed a coma 1′ in diameter, centrally condensed, with a faint tail 3′ long in position angle 70° (Van Biesbroeck).

During the year unsuccessful searches for five other periodic comets, whose returns had been predicted (*Handbook B.A.A.* 1953), were made by Van Biesbroeck, H. M. Jeffers, L. Kresák, Miss Roemer and others. Of these, comets Borrelly (recovered early in 1954), Giacobini-Zinner* and Tuttle were badly placed for observation, and only limited searches could be made at times when they were probably very faint. An extended search for the comet Jackson-Neujmin (1936 IV), covering variations in T from about −20 to +40 days from the predicted date, and brightness down to about magnitude 16 or 17, was made by Miss E. Roemer with the 20-inch astrograph at the Lick Observatory between September 3 and 6. The elements for the orbit were however considered to be very uncertain and it seems one must now regard this comet as lost. Searches for the comet 1948 n, Honda-Mrkos-Pajdušáková,

* A meteor shower attributed to P/Giacobini–Zinner had, however, been recorded on 1952 October 9 (*Obs.*, **72**, 250, 1952).

were made in accordance with the original prediction which was subsequently found to be in error—the comet was recovered early in 1954.

The comets reported still under observation in the new year (1954), or possibly within reach later, in addition to the two annual ones, were :

1953 a	Mrkos-Honda	1953 f	P/Encke
1953 b	P/Brooks (2)	1953 g	Abell
1953 c	P/Pons-Brooks	1953 h	Pajdušáková
1953 d	P/Reinmuth (2)	1953 i	P/Finlay

The continuation of the annual numerical designations of comets (in order of perihelion passage) has recently been published by the I.A.U. Bureau.* It is included here for convenience of reference, in Table II.

TABLE II

Comet	T	Name	Year and letter
1948 I	Feb. 16·4	Bester	1947 k
II	Feb. 16·7	Mrkos	1948 a
III	Apr. 9·0	Johnson	1948 j
IV	May 15·9	Honda-Bernasconi	1948 g
V	May 16·6	Pajdušáková-Mrkos	1948 d
VI	June 25·8	P/Whipple	1947 g
VII	Aug. 23·6	P/Schwassmann-Wachmann (2)	1947 l
VIII	Sept. 16·1	P/Forbes	1948 e
IX	Oct. 4·7	P/Ashbrook-Jackson	1948 i
X	Oct. 22·9	Bester	1948 m
XI	Oct. 27·4	Eclipse Comet	1948 l
XII	Nov. 17·7	P/Honda-Mrkos-Pajdušáková	1948 n
XIII	Dec. 15·9	P/Neujmin (1)	1948 f
1949 I	May 1·1	Wirtanen	1948 h
II	Sept. 16·2	P/Johnson	1949 d
III	Oct. 13	P/Wilson-Harrington	1949 g
IV	Oct. 26·4	Bappu-Bok-Newkirk	1949 c
V	Nov. 11·3	P/Väisälä	1949 h
VI	Nov. 26·7	P/Shajn-Schaldach	1949 e

Table III, giving the elements of cometary orbits, is arranged as in previous reports : the comets are listed in order of perihelion date; the symbol P/ indicates a periodic comet, and *p* after the perihelion date that the elements were predicted ones. The perihelion date deduced from observations, when not given in a set of elements in the table, will be found in the notes appended.

REFERENCES AND NOTES TO TABLE OF ELEMENTS

1914 IV Campbell-Westland-Lund. (1) J. Dobrzycki, *Poznan Obs. Reprint*, No. 28, 1953. Definitive, from 167 observations covering 63^d. Osc. epoch 1914 October 18·0 Berlin M.T.

1925 I P/Wolf (2), previously 1924 IV. (2) Antoni Przybylski, MS. Definitive, from 21 observations (including three not previously used) covering 54^d. Osc. epoch 1925 January 10·0 U.T. The period, 2771 days, uncertain by about 10 to 15 days, is 36 days longer than S. Kanda gave. Tisserand's criterion 0·5379 compares with 0·5360 for P/Harrington, 1951 k, so identity seems very probable.

1925 III Reid. (3) St Wierzbiński, *U.A.I.C.* 1432. Definitive, from 283 observations covering 647^d. Osc. epoch 1925 December 19·0 U.T.

* *U.A.I.C.* 1448. This continues the list previously quoted in *M.N.*, **112**, 341, 1952. The perihelion dates (T) are from orbits noted in these annual reports.

1944 III P/du Toit (1). (4) Jorge Bobone, MS. (to be published in *Contrib. Observ. Córdoba*). Revised elements from 18 observations covering 146^d, taking account of perturbations by Earth, Jupiter and Saturn. Osc. epoch 1944 November 6·0 U.T. He gives a prediction for 1959.

1944 IV Van Gent. (5) Antoni Przybylski, MS. Definitive, from 34 observations covering 436^d. Osc. epoch 1944 December 16·0 U.T.

1946 IV P/Brooks (2). (6) A. Dubiago, *Astron. Circ.* (U.S.S.R.) 137. Revised elements based on his investigation of the orbit 1925–46. Osc. epoch 1946 August 28·0 U.T.

1947 X Honda. (7) K. Hurukawa, *N.A.Z.*, **7**, No. 9, 33, 1953. Orbit from 8 Johannesburg observations covering 21^d. The results are uncertain owing chiefly to the size and diffuseness of the images measured. The computer states: "Three basic normal places have the errors about 20″ in arc."

1948 I Bester. (8) G. Merton, MS. From 3 positions, using 6 Lick Observatory observations, covering 291^d. Middle place residuals of around 30″ indicate, some deviation from the parabola. Preliminary figures for a general solution gave $1/a = +0{\cdot}011$, $e = 0{\cdot}992$.

1948 VII P/Schwassmann-Wachmann (2). (9) Cameron Dinwoodie, *Handbook B.A.A.* 1954, 49. Improved elements by correction of Rasmusen's 1949 elements, linked to 1942, using 7 Lick observations in 1949. The printed value of n should be corrected to $0^{\circ}{\cdot}15102996$. Osc. epoch 1949 January 4·0 U.T.

1948 XII P/Honda-Mrkos-Pajdušáková. (10) G. Merton, *U.A.I.C.* 1442. Improved orbit from 3 normal positions, based on selected material, covering 33^d.

1951 f P/Tuttle-Giacobini-Kresák. (11) L. Kresák, *Bul. Ast. Inst. Czechoslovakia*, **4**, 32, 1953. From 35 observations, covering 95^d, made at the Skalnaté Pleso Observatory.

1952 e Harrington. (12) P. Prêtre, *U.A.I.C.* 1408. From 13 observations covering 120^d.

1953 a Mrkos-Honda. (13) K. Hurukawa, *U.A.I.C.* 1424. From one observation and two normal positions covering 136^d.

1953 b P/Brooks (2). (14) A. Dubiago, *Astron. Circ.* (U.S.S.R.) 137. Prediction based on his previous investigations—see ref. (6) above. Osc. epoch 1953 August 11·0. Observation indicated perihelion 1953 August 7·33 U.T.

1953 e P/Harrington. (15) Joseph L. Brady, *U.A.I.C.* 1422. From 5 observations (badly distributed) covering 21^d.

1953 i P/Finlay. (16) R. Luss, *Handbook B.A.A.* 1953, 47. Prediction from that for 1947 based on S. Kanda's elements for 1926 and subsequent predictions by A. C. D. Crommelin, C. Dinwoodie and M. Sumner. Osc. epoch 1953 December 9·0 U.T. (17) G. Merton, *U.A.I.C.* 1440. Revised elements using 5 observations covering 28^d, with assumed period 2487·3 days.

1953 h Pajdušáková. (18) Jorge Bobone, *U.A.I.C.* 1448. From 3 observations covering 24^d.

1953 d P/Reinmuth (2). (19) E. K. Rabe, *Handbook B.A.A.* 1954, 47. Prediction based on his definitive orbit 1947–48, with perturbations by Jupiter and Saturn. Osc. epoch 1954 September 15·0 U.T. Observation indicated perihelion passage about 1954 March 27·6 U.T.

1953 c P/Pons-Brooks. (20) P. Herget and P. Musen, *U.A.I.C.* 1411. Musen's elements, from Herget's predicted perturbed coordinates based on his definitive investigation 1812–1884. Osc. epoch 1954 June 22·0. Observations indicated perihelion passage 1954 May 22·91.

1953 f P/Encke. (21) S. G. Makower, *Astron. Circ.* (U.S.S.R.) 135. Prediction based on his definitive investigation of apparitions 1937–51, including recalculated perturbations (Mercury to Neptune). Osc. epoch 1954 May 18·0. Observation indicated perihelion passage about 1954 July 2·519.

1953 g Abell. (22) A. D. Dubiago, *Astron. Circ.* (U.S.S.R.) 144. Representing 10 observations covering 40^d. The ellipticity is uncertain.

Additional Notes

Individual Comets

1951, unidentified comets. The images of three unidentified comets, magnitudes about 14 to 15, have been found on minor planet survey plates taken at the McDonald Observatory on 1951 April 2, 9 and May 28; *U.A.I.C.* 1437, 1445.

TABLE III. *The Elements*

Comet		*T* G.M.T. before 1925·0 U.T. from 1925·0	*q*	*e*
1914 IV	Campbell-W.-Lunt	1914 Aug. 4·9754	0·712833	0·998844
1925 I	P/Wolf (2)	1925 Jan. 10·9570	2·427978	0·371169
1925 III	Reid	1925 July 29·8553	1·633208	0·995072
1944 III	P/du Toit (1)	1944 June 17·4951	1·276941	0·788059
1944 IV	Van Gent	1944 July 17·6132	2·225935	1·002083
1946 IV	P/Brooks (2)	1946 Aug. 25·7948	1·878842	0·484599
1947 X	Honda	1947 Nov. 17·906	0·75309	1·0
1948 I	Bester	1948 Feb. 16·4150	0·748329	1·0
1948 VII	P/Schw.-Wach. (2)	1948 Aug. 23·6215	2·151956	0·383775
1948 XII	P/Honda-Mrkos-P.	1948 Nov. 17·7103	0·559061	0·814314
1951 f	P/Tuttle-G.-Kresák	1951 May 9·3734	1·116599	0·641343
1952 e	Harrington	1953 Jan. 5·4266	1·665002	0·996173
1953 a	Mrkos-Honda	1953 May 26·4366	1·022114	0·997200
1953 b	P/Brooks (2)	1953 Aug. 7·368*p*	1·866086	0·486677
1953 e	P/Harrington	1953 Sept. 22·4102	1·691169	0·533492
1953 i	P/Finlay	1953 Dec. 19·246*p*	1·03528	0·711721
		1953 Dec. 25·8836	1·048902	0·708044
1953 h	Pajdušáková	1954 Jan. 24·6654	0·072091	1·0
1953 d	P/Reinmuth (2)	1954 Mar. 27·052*p*	1·867228	0·468962
1953 c	P/Pons-Brooks	1954 May 27·383*p*	0·773968	0·954810
1953 f	P/Encke	1954 July 2·522*p*	0·338378	0·847313
1953 g	Abell	1954 July 7·4651	0·970513	0·999439

1952 a P/Harrington-Wilson. L. Kresák suggests possible identity with 1916 I P/Taylor, the value of Tisserand's criterion being respectively 0·5554 and 0·5510; *U.A.I.C.* 1426. However, the elements predicted by S. Kanda for Taylor's comet in 1935 and 1942 (*Tokyo Astron. Obs. Report*, **9**, No. 1, 1942) seem to indicate that such identity is improbable. Kresák intends to investigate the matter further.

P/Faye. V. I. Cherednichenko: " Secular Change of Brightness of the short-period Comet Faye ", *Pub. Kiev Astron. Obs.* No. 5, 83, 1953.

P/Brooks (2). V. P. Konopleva: " On the change of Brightness of the short-period Comets Brorsen I and Brooks II ", *Pub. Kiev Astron. Obs.*, No. 5, 59, 1953.

P/Brorsen (1). See note on P/Brooks (2) above.

P/Tuttle-Giacobini-Kresák. L. Kresák: " The periodic Comet Tuttle (1858 III)-Giacobini (1907 III)-Kresák (1951) ", *Bul. Astron. Institutes of Czechoslovakia*, **4**, 27, 1953—see Table III, ref. (11) above. He intends to compute the perturbed orbit back to the apparition of 1858, and to clear up Spitaler's single observation of 1884, and to provide a prediction for the next return.

P/Wolf (1). M. Kamieński: " The close approach of the Comet P/Wolf I to Jupiter in 1756—Preliminary Results ", *Bul. Acad. Polonaise* (Cracovie), Série A, 1951, 417. " List of Prof. M. Kamieński's papers on the motion and on origin of the Comet P/Wolf I " (1908–1952), *Acta Astron.*, Sér. **c**, **5**, 44, 1953.

General

J. Bouška: " Cometary Study X—Absolute Brightness of Comets 1950 b, 1951 a, 1951 b ", *Bul. Astron. Inst. of Czechoslovakia*, **4**, 119, 1953.

Salah El-Din Hamid and Fred L. Whipple: " On the Motions of 64 Long-period Comets ", *A.J.*, **58**, No. 1208, 100, 1953; *Harvard Reprint* II, No. 48, 1953.

C. Hoffmeister: " Das Problem des Ursprungs der Kometen ", *Mitt. Sternwarte Sonneberg*, No. 42, 1953.

of Cometary Orbits

Period (years)	ω	☊	i	Equinox	Computer	Ref.	Comet
	°	°	°				
...	270·3556	0·3810	77·8279	1914·0	Dobrzycki	1	1914 IV
7·59	180·1001	260·3189	23·6781	1925·0	Przybylski	2	1925 I
6034	259·2720	5·9891	26·9724	1925·0	St Wierzbiński	3	1925 III
14·79	257·0198	22·4539	18·7455	1950·0	Bobone	4	1944 III
...	336·9778	202·8028	95·0163	1950·0	Przybylski	5	1944 IV
6·96	195·6077	177·6938	5·5390	1950·0	Dubiago	6	1946 IV
...	221·241	311·920	106·286	1947·0	Hurukawa	7	1947 X
...	350·2126	270·7090	140·5690	1948·0	Merton	8	1948 I
6·53	358·1140	126·0114	3·7237	1950·0	Dinwoodie	9	1948 VII
5·22	184·1082	233·0933	13·1628	1950·0	Merton	10	1948 XII
5·49	37·9455	165·6411	13·7969	1951·0	Kresák	11	1951 f
9075	191·6373	220·7169	59·1242	1952·0	Prêtre	12	1952 e
6974	85·7455	275·2262	93·8585	1953·0	Hurukawa	13	1953 a
6·93	195·6916	177·6788	5·5506	1950·0	Dubiago	14	1953 b
6·90	219·5852	136·5995	11·5569	1953·0	Brady	15	1953 e
6·81	321·264	45·291	3·463	1950·0	Luss	16	1953 i
6·81	321·0688	45·4198	3·4386	1950·0	Merton	17	1953 i
...	94·0723	114·6250	13·5737	1953·0	Bobone	18	1953 h
6·59	44·1905	297·2233	7·1162	1950·0	Rabe	19	1953 d
70·88	199·0222	255·1902	74·1790	1950·0	Herget, Musen	20	1953 c
3·30	185·1919	334·7541	12·3752	1950·0	Makower	21	1953 f
...	194·4575	2·2952	53·2009	1953·0	Dubiago	22	1953 g

R. A. Lyttleton : " *The Comets and their Origin* ", Cambridge, 1953.

S. M. Polovska : " The Radio Emission of Comets ", *A.J.* (U.S.S.R.), **30,** 68, 1953.

J. G. Porter : "*Comets and Meteor Streams*", The International Astrophysics Series, vol. 2, London, 1952.

N. Richter : " Kometen—ein kosmischer Auflösungsprozess ", *Mitt. Sternwarte Sonneberg*, No. 43, 1953.

K. A. Steins : " On the Origin of long-period Comets ", *A.J.* (U.S.S.R.), **30,** 184, 1953.

P. Swings (Edit.) : " La Physique des Comètes ", *Mem. Inst. Astrophys. de Liège*, No. 352, Louvain, 1953. A collection of some 31 communications presented at the fourth International Astrophysical Symposium at Liège, 1952 September 19–21, together with brief accounts of the discussions.

S. K. Vsessviatsky : " New work on the Origin of Comets and the Theory of Eruption ", *Pub. Kiev Astron. Obs.*, No. 5, 3, 1953.

J. Witkowski : " Oppenheim's Phenomenon and its bearing on the Origin of Comets ", *Bul. Soc. Amis des Sci. Poznan*, Série B, **12,** 205, 1953; *Poznan Obs. Reprint* No. 29, 1953.

Corrigenda

107, 109, Table, ref. 7, P/Neujmin (2). The integral part of the angle ω should read "193", not "194" which was a misprint in both sets of elements on p. 54 of *Pulkova Obs. Circ.*, **32,** 1941; *cf.* later version, *M.N.*, **109,** 255, ref. 4.

113, 388, Table I. Under date column for " 1951 " read " 1952 ".

113, 390 bottom and 391 Table, ref. (7), the name of the computer is to read " Hurukawa ".

G. MERTON.

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE GOLD MEDAL TO DR WALTER BAADE

Dr John Jackson

The Gold Medal of the Society has been awarded by the Council to Dr Walter Baade of the Mount Wilson and Palomar Observatories for his observational work on galactic and extragalactic objects. It is now my duty to give an account of our medallist's work, and I may say at the outset that in preparing this address I have come to admire more and more his contributions to our science. Throughout more than 30 years his aim has been to get such observations as would enable us to form an accurate picture of the objects scattered through space. As new apparatus has become available and new techniques developed he has been in the forefront in applying them to the solution of new problems, some of which could hardly have been formulated earlier. He has ever striven to extend his observations to the most distant objects which could be observed with the telescopes at his disposal, and at the same time he has strengthened the basis of his deductions by setting up standards of magnitude for the faintest stars. We now add Baade's name to a list which already contains those of Shapley and Hubble who have worked with the same telescopes on the same or similar subjects.

Educated at Göttingen, Baade joined the staff of the Hamburg Observatory in 1919 October and for the next 12 years he worked on a variety of problems there. The principal instrument he used was the most powerful one of the Observatory—a reflector of 1 metre aperture and the short focal length of 3 metres. Although from the first he showed that his interest lay in the new fields of investigation which were opening up from the study of variable stars, and particularly those of the Cepheid type, a good deal of his time was given up to the more or less routine observation of bodies in the solar system. In the records of Hamburg Observatory we read of his searching for missing minor planets, discovering new ones and measuring their positions carefully. He also made observations of the positions and form of comets and incidentally discovered a new comet of his own, 1922 c.

Our medallist appears to have been specially attracted by the investigations which Shapley had made at Mt Wilson and was continuing at Harvard, and alone amongst European observers he attempted to emulate Shapley's results with the smaller instrument at his disposal in a poorer climate. In fact we could easily fall into thinking that Baade was working with the 60-inch or 100-inch and not with a 1-metre reflector.

It is convenient at this stage to refer briefly to the methods which have been developed for determining the distances of remote objects. Before any real progress could be made the distances of some stars had to be determined as accurately as possible by the trigonometric method. The Yale General Catalogue of Trigonometric Parallaxes published two years ago gives results for 5822 stars. 751 of these have a parallax of $+0''\cdot050$ or more and for most of them the probable error does not exceed $\pm 0''\cdot008$ or $\pm 0''\cdot009$, say 18 per cent

or less of the parallaxes. That might seem a sufficient basis for determining such characteristics as the absolute brightness of different types of stars. As is well known, however, most of the 751 stars are dwarfs: there are very few giants, let alone supergiants, so important for determining great distances by indirect methods. In 1919 when our medallist started work only a fraction of these parallaxes had been determined. But some indirect methods were in use. That dependent on a combination of proper motions and radial velocities is of course beyond reproach for determining the mean parallaxes of groups of stars and helped very considerably to determine absolute magnitudes of stars too remote for successful trigonometric observation of the individual stars. The most obvious way of determining the distance of remote stars is from the difference in their apparent and real brightness. Once the absolute brightness of a star can be estimated from its spectrum, mode of variation or in any other way, then its distance can be simply computed from its apparent brightness—provided there is no absorption of light in space. Unfortunately absorption of light in space can be large, and this, perhaps more than uncertainty in absolute magnitudes, may prove the greatest stumbling block in determining the distances of remote bodies. I might add that there is no insurmountable difficulty in determining the apparent brightness of stars—perhaps for that very reason, almost to the present time, exact photometry has too frequently been treated as the Cinderella of astronomy.

It is interesting sometimes to speculate on the way our science would have developed if some of the objects found in the southern sky had been visible from northern observatories. For instance if α Centauri had been a northern star, surely its brightness, large proper motion and orbital motion would have led to a successful parallax determination before 1838. Again of special importance to our medallist's work is the part played by the Magellanic Clouds. If these had been visible from a northern observatory when would the famous period-luminosity law for Cepheid variables have been discovered? Probably about the same time. For by great good fortune Harvard Observatory—the pioneer in applying photographic methods to the faintest objects and in investigations of faint variable stars—had established a southern station at Arequipa in Peru and through two decades had been photographing the heavens. The story has often been told of how this led in 1912 to the discovery by Miss Leavitt of a simple relationship between the period of variation of Cepheid variables in the Small Magellanic Cloud and their brightness. This of course referred to apparent magnitudes, but it was quickly recognized that as the distance of all the variables in the Clouds would be approximately the same the law referred to absolute as well as apparent magnitudes. A new method of determining the distances of the Magellanic Clouds and of clusters containing Cepheid-type variables from apparent magnitudes thus became available as soon as the zero point could be established. The determination of the zero point was one of great difficulty as there were only a few Cepheids known in our system and for these the proper motions were small and not well determined. However Hertzsprung made a determination which has proved remarkably reliable although it is recognized that we have not yet got a really definitive result. Shapley's researches on the distances of clusters and the extent of the Galaxy followed during the first World War.

At Hamburg, Baade made observations with the reflector for the determination of stellar magnitudes and colour, and carried on investigations on variable stars wherever they were to be found. Amongst the objects he investigated at this stage were NGC 5466 and 5053. Both of these objects look like faint open clusters but our medallist found that long exposures brought up a great number of faint stars over a circular area with a strong condensation towards the centre. These are characteristics of globular clusters and he clinched the matter by finding variable stars of the Cepheid type in both clusters. He was thus able to determine the distances. It is well known that Shapley had extended his method of determining the distances of star clusters from the brightness of individual variables to the total brightness and the apparent diameter of the cluster. This method he had applied to the two clusters mentioned. It might have been expected that from the unusual appearance of the clusters Shapley's rougher method would be in error but our medallist's determinations closely confirmed the earlier ones, the distance of both clusters being about 19 000 parsecs. This work depended on determinations of the brightness of stars below magnitude 16·0.

Baade's searches for faint variable stars were not confined to globular clusters. He observed in a number of regions to find variations in the distribution of variable stars of different type. He made a special search in regions of the Milky Way in Sagitta and Cygnus. Here he found 124 new variables, about half of them eclipsing variables and a fifth long-period variables. Only a small number were of the Cepheid type. This is a general characteristic of galactic clusters as distinct from globular clusters in which the Cepheid variables predominate. Another interesting discovery made by our medallist at this time was a cluster of about 60 nebulae fainter than the 16th magnitude in an area of only 0·06 square degrees in Ursa Major. This was the richest concentration of nebulae known in any region of the sky. He calculated that it was 15 times as far away as the well-known cluster of nebulae in Coma and Virgo, so that if we accept Hubble's estimate of the latter as 10 million light years the distance of the Ursa Major cluster must be 150 million light years—a very great distance to be determined in 1928.

For the year 1926–27 Baade went to U.S.A. and Canada with a Rockefeller Foundation Fellowship. This gave him the opportunity of meeting colleagues working there with large reflectors, and in 1931 he joined the staff of the Mount Wilson Observatory to work with Hubble on the direct photography and photometry of nebulae and star clusters—the observational work in which he had shown such keen interest at Hamburg.

Amongst the best-known photographs of the Milky Way are those of the beautiful wispy cloud in Cygnus. I have already referred to the fact that while at Hamburg our medallist had searched this region for variable stars and found many of them to be eclipsing variables. Soon after he migrated to Mount Wilson he undertook an investigation for determining its distance, using all the criteria available. We think so often of the Cepheid variables as the most useful stars for determining distances from the difference between their apparent and their real brightness that we may neglect the possibility of using other types of star. Any type of star which can be clearly recognized and for which the intrinsic brightness is known can be used in determining distances. For the Cygnus cloud our medallist depended on three classes of stars, eclipsing

variables, long-period variables and early B-type stars. There is no need for me to go into the details here today, except to say that for some of the very faint stars spectrograms made with the very fast Rayton spectrograph attached to the 100-inch reflector required exposures up to 4 hours. The three types of star indicated distance moduli of 12·5, 13·0 and 12·7, and the distance modulus of 12·7 was adopted. There then arose the question of absorption of light in space. From the colour indices of 80 stars of type B8 to A5 a colour excess of 0·25 magnitude was found. Assuming pure Rayleigh scattering as an explanation of this, Baade deduced the upper limit of the distance of the Cygnus cloud to be 2630 parsecs as compared with 3500 which would follow from the adopted modulus if no correction for absorption had been applied.

Although Cepheid variables are not generally associated with galactic clusters to any extent, our medallist found a few of them in the Cygnus cloud. They gave disappointing results. Four of long period were much too faint to fit in with the adopted modulus. Two of them could be explained by heavy absorption and the other two might be much further off than the cloud. Five short-period cluster-type variables also failed to fit into the general result, but they can be explained as belonging to the general galactic field of such objects. I quote these results to show the inconsistencies met with in the observations and the care with which they were investigated by our medallist.

Passing over other work of a similar nature, I turn to a different branch of our medallist's work—that on novae and supernovae. Since early times the sudden appearances of new stars have been a source of wonder to mankind. These new stars sometimes rival or surpass the brightest of the normal stars and have appeared sufficiently frequently to form a special subject of study. The fact that they do not alter their positions amongst the other stars naturally led to them being considered as stars with a real brightness presumably commensurate with their apparent brightness. Attempts to determine their distance by the most refined trigonometric methods have only proved them to be very distant, so that at maximum brilliance they must be reckoned amongst the brightest of stellar objects. In 1917 Ritchey discovered a nova in the spiral nebula NGC 6946 and this was followed by the discovery of many other novae in other extragalactic systems. If therefore a definite absolute magnitude could be attributed to these novae a new way seemed open to determine the distances of the systems. The first attempts by H. D. Curtis and K. Lundmark to apply the method were disappointing and seemed to indicate a large dispersion in the luminosities. I now quote from Baade:

"This feature is well illustrated by the novae of the Andromeda nebula. The first observed in this near-by extragalactic system, the famous nova of 1885, S Andromedae, reached a maximum apparent visual brightness of 7·2, a brightness nearly comparable with that of the whole nebula. On the other hand the many novae discovered in the Andromeda nebula after a systematic search had begun in 1917 were all faint objects, ranging in apparent magnitude from 16 to 18. The unusually large range of 11 magnitudes in the observed luminosities of these novae was disturbing because it indicated either a very large dispersion in the absolute magnitudes or the existence of two groups of novae differing in luminosity by a factor of the order of 10 000. A few years later Hubble's investigation of the Andromeda nebula left no doubt that the second alternative had to be adopted. The 85 faint novae observed in this nebula between 1917 and

1927 had all the characteristics of a well-defined group. Their brightness at maximum showed a range of only 3 or 4 magnitudes with a pronounced frequency maximum at $m = 17{\cdot}3$. Moreover their mean absolute maximum $M = -5{\cdot}7$ identified them with the galactic novae.

" Compared with these common novae of which an average of 30 appear annually in the Andromeda nebula, S Andromedae with an absolute brightness of $M = -15{\cdot}0$ stands out as a nova *sui generis*. But S Andromedae, though exceptional, is by no means a singular case. For if we exclude from the list of all novae which have been found in extragalactic systems the few faint novae discovered in other members of the local group of galaxies, which are clearly common novae, the remaining examples are to be classed with S Andromedae because they reached apparent magnitudes comparable with the integrated apparent magnitudes of the systems in which they appeared."

Our medallist therefore concluded that besides the class of fainter novae, to which most of our galactic novae belong, there was a class of supernovae which on the average were nearly 10 magnitudes or 10 000 times brighter, and therefore visible in nebulae too far distant for the fainter novae to be observed in them. From the evidence of novae in our own system and the local group, supernovae were rare compared with ordinary novae. About the same time Minkowski obtained spectra of six supernovae and found their spectra to be quite different from those of all other stars, including ordinary novae. The spectra of the supernovae were so distinct from other spectra that they could be accepted as certain confirmation of the class even when very small dispersion was used.

Baade then set out to determine as accurately as possible the mean absolute magnitude and dispersion of the supernovae observed in extragalactic nebulae. After rejecting all the objects believed to be common novae he was left with 18 which might be supernovae, several of them observed before 1917. It was first of all necessary to examine the published magnitudes, some of which were only rough estimates. Where possible he obtained revised estimates from the discoverers and then he reduced them all to a photometric system based on stars of the north polar sequence. How much this was necessary is shown by the fact that as a result of this revision the mean final magnitude was about a magnitude fainter than the original estimate.

It is not necessary here to go into the details, but the data are meagre enough as is fully explained by our medallist. Of the 18 objects selected as possible supernovae 8 had to be rejected because there was no distance modulus or because the observations did not give a reliable value of the apparent maximum; of the remaining 10, six were in the Virgo cluster and so depended on the same distance modulus. The ten absolute magnitudes range from $-12{\cdot}3$ to $-16{\cdot}6$ with a mean of $-14{\cdot}3$ as compared with $-7{\cdot}0$ for ordinary novae ranging from about $-5{\cdot}4$ to $-8{\cdot}6$.

By this time it had been decided to undertake a systematic search for new supernovae in selected extragalactic nebulae, so that their light curves, spectra and other characteristics might be closely studied. The most suitable instrument for the search is a Schmidt reflector and by 1936 an 18-inch telescope of this type was available at Palomar where the search was conducted by Zwicky. Two of the first-fruits of this search were supernovae found in the late-type spirals IC 4182 and NGC 1003. The first of these discovered in 1937 August was observed till 1939 May when the magnitude had fallen to 21 from its maximum, estimated at

8·2. The second which was more than 4 magnitudes fainter at maximum was followed for more than a year. In the meantime Minkowski had succeeded in getting numerous spectra of these supernovae, the first till 339 days after maximum when the magnitude had fallen to about 17. It was found that both in light curve and spectroscopic changes these two supernovae followed very nearly the same pattern, and that incomplete observations for other supernovae would fit into the same scheme. Nevertheless it is necessary to be careful and not slavishly accept results from a few objects as if they could be universally applied. For example the use of absolute magnitudes of supernovae and of complete nebulae will sometimes give very discordant results. IC 4182 was specially selected for observation as it was known to have a very low surface brightness. Its integrated photographic brightness is only 13·5 while its supernova reached 8·2, or more than 5 magnitudes brighter. On the other hand the supernova in the Andromeda nebula when it reached magnitude 7·2 was still 2·7 magnitudes fainter than the nebula. The supernova in IC 4182 was estimated to have an absolute magnitude of $-16{\cdot}6$ and has already been referred to as the brightest known supernova, that in NGC 1003 was an average one of absolute magnitude $-14{\cdot}0$.

The discovery of supernovae by Zwicky with the Schmidt camera at Palomar continued and their observation was followed up by Baade, Zwicky and Minkowski. For some time the stars continued to follow closely both spectroscopically and photometrically the pattern set up by the first two. But, as every observer knows, something new is bound to turn up if only you continue long enough. The Californian astronomers had not long to wait, for soon Minkowski found supernovae with emission spectra not so unintelligible as those provided by the earlier ones. He designated the original supernovae as of Type I and the new ones as of Type II. Supernovae of Type II differ from those of Type I in the transition from a continuous spectrum at maximum to an emission spectrum whose main constituents can be readily identified. It was suggested that supernovae of Type II are intermediate between ordinary novae and supernovae of Type I. Baade also found in the light curves of supernovae of Type II a conspicuous shoulder after maximum, not found in supernovae of Type I. Four objects of Type II were systematically fainter at maximum than those of Type I, averaging less than -12 as compared with $-14{\cdot}3$ previously found. If a division of supernovae into Types I and II is made, the fainter ones included in the earlier list may now be ascribed to Type II instead of Type I.

While the investigations of supernovae in extragalactic systems were going on at Mt Wilson and Palomar an exhaustive examination of galactic novae was inaugurated. Three objects had already been considered as possible supernovae, principally on account of the extreme apparent magnitude they reached. These were the famous novae of 1054, 1572 (Tycho's nova) and 1604 (Kepler's nova, B Cass). A number of investigators, in particular Lundmark, had already given a good deal of attention to these novae and collected the historical records. For the nova of 1054 there was no very accurate position, but a most unusual object, the Crab Nebula, was sufficiently near to attract attention and then to be recognized as a product of the explosion that had produced the nova. From the apparent rate of expansion together with radial velocity determinations it is a simple matter to deduce the distance—on certain assumptions. For the novae in 1572 and 1604 there were sufficient records of the light variation for our

medallist to construct light curves of very considerable accuracy and these he found to be remarkably similar to those of the two supernovae of Type I which he had carefully determined. We know that an expanding nebulosity is often seen after the outburst of a nova, and it appeared certain that 900 years after its outburst the supernova of 1054 had left behind a prominent relic in the Crab Nebula. It was therefore natural to search for relics of the bright novae of 1572 and 1604. And for these novae, positions accurate within 1′ or less could be determined from the observations of Tycho Brahe and Fabricius, but so far no relics had been found. Our medallist instituted exhaustive searches. As the supernova of 1604 had appeared in a heavily obscured part of the Milky Way the search was carried out with one of the new red-sensitive plates and a red filter (6300–6700 A). This, combined with a 2-hour exposure with the 100-inch reflector, revealed a small patch of nebulosity about 30″ distant from the expected position. In the photographic region (3600–5000 A) the nebulosity is extremely faint and might easily be missed. The photographic surface brightness is only equal to a star of magnitude 25·2 per square second of arc or about 4 magnitudes fainter than that of the Crab Nebula. Baade has searched for a stellar remnant but so far has not discovered one. He is fairly certain, however, that the nebula he has found is composed of matter ejected by the nova, not only from its position but from the fact that Humason and Minkowski have determined the large radial velocity of 200 km/sec. We may speculate on finding the tangential motion in 20 or 30 years from now and of associating this with radial velocities for determination of the distance. But in the meantime I turn to the other supernova: that of 1572. All attempts to find any remnant of it have so far failed. To quote Baade's own words:

"If any nebulosity exists in the place of B Cass it must have a photographic surface brightness fainter than 25 mag. per square second of arc, which for extended nebulosities represents about the limit attainable with an *f*/5 reflector. The search for a blue star . . . proved equally unsuccessful. No such star down to photographic magnitude 19·0 could be found on the plates . . . On account of its high declination B Cass cannot be reached with the 100-inch telescope. However there is every prospect that it will be found when the 200-inch telescope comes into operation."

The Mount Wilson observers then turned their attention to the ordinary novae which have appeared in our system in more recent times. It is hoped to get information as to the distances of these novae and other data which may lead to a discovery of the mechanism of ejection of the matter which forms the nebulosity. Participating in this work with Baade is Humason who has made spectrograms with exposure times up to 20 hours. Much work has already been done and some of the results seem to indicate that the gulf between ordinary novae and supernovae is not so great as had been believed from the earlier discussions from old and less complete data.

As so much of Baade's work has depended on the use of photographic plates, I would like to recall the progress made in their use for observing faint stars during the past century. In 1850 at the Harvard Observatory they succeeded in photographing α Lyrae with the great equatorial in 100 seconds. In 1857 Professor G. P. Bond reported how progress had been made rapidly, almost from week to week, so that they were able to photograph stars to the sixth magnitude. Then he made an optimistic forecast, what we might call wishful thinking:

" But could we but press on we should soon be able to say what we can and what we cannot accomplish in stellar photography. The latter limits we certainly have not yet reached. At present the chief object of attention must be to improve the sensitiveness of the plates, to which, I am assured by high authorities in chemistry, there is scarcely any limit to be put in point of theory. Suppose we are able finally to obtain pictures of seventh magnitude stars. It is reasonable to suppose that, on *some lofty mountain and in a purer atmosphere*, we might with the same telescope, include the eighth magnitude. To increase the size of the telescope three-fold in aperture is a practicable thing, if the money can be found. This would increase the brightness of stellar images, say, eightfold and we should be able then to photograph all the stars to the tenth and eleventh magnitude inclusive. There is nothing, then, so extravagant in predicting a future application of photography to stellar astronomy on a most magnificent scale. It is, even at this moment, simply a question of finding one or two hundred thousand dollars to make the telescope with and to keep up the experiments."

The biggest advance Bond saw was one of about $2\frac{1}{2}$ magnitudes to be obtained by increasing the aperture from 15 to 45 inches. Now Baade writes of getting stars to magnitude $22\frac{1}{2}$. How are the 12 additional magnitudes representing a factor of 60 000 obtained? Bond expected most by increasing the aperture. By increasing the aperture to 100 inches we have gained $1\frac{1}{2}$ magnitudes more, and a further $1\frac{1}{2}$ magnitudes by increasing it to 200 inches. But we have made much progress in directions hardly entertained by Bond. When I was at Greenwich we considered that the 30-inch reflector was 5 times as fast as the 26-inch refractor. By changing from the long-focus refractor to the short-focus reflector there must be a gain of at least 2 magnitudes. That explains 5 magnitudes beyond Bond's limit. Improvement in clockwork and engineering generally have enabled us to increase exposure times from minutes to hours, giving us perhaps 3 extra magnitudes. So that of the 12 magnitude improvement beyond the hopeful forecast of 1857 we have explained about eight, leaving 4 to increased sensitivity of the photographic plate.

And this is by no means the whole story. These last 4 magnitudes are available to all without increasing the size and cost of the telescope. You might now be thinking that I am going to predict great advances in the future; if so, I am afraid that I am going to disappoint you. It is not the caution, usually attributed to my race, but the laws of nature that compel me to this view. The fact is that we are approaching the stage when the fogging due to the light of the night sky is of the same order of intensity as that of the images formed by the faintest stars. Increase in speed of the plates can only help by enabling us to cut down the exposure time required. Those of you who have been interested in checking Einstein's prediction of the deflection of star light by the attraction of the Sun know how fogging due to coronal light may be fatal. We know what exposure is necessary to get measurable images of the field stars—it may be anything from a few seconds to minutes—and we know that every additional second tends to blot out the most important stars near the Sun. In this connection I would like to quote from the report on the work at Mount Wilson during the war (1942–43).

" These last investigations which require long exposures on the fastest available plates, would probably have been impossible under normal conditions on Mount Wilson. Since the dim-out of the Los Angeles valley, however, the

Observatory enjoys again a perfectly dark sky except for a trace of illumination close to the south-western horizon. As a result direct exposures with the reflectors on the fast Eastman 103 a–O plates formerly limited to about 45 minutes can now be extended to 90 or 120 minutes. The corresponding gain in limiting magnitude is best illustrated by some plates of the Andromeda nebula which for the first time show the hitherto unresolved inner part of the nebula sprinkled with a multitude of faint stars just below the twenty-first magnitude."

There was, however, one last ray of hope and our medallist has seized it with both hands. Everyone knows that the photographic plate is sensitive to light far into the ultra-violet and that our atmosphere is opaque to such light. On the other hand at the red end of the spectrum and beyond there are large regions to which our atmosphere is at least fairly transparent but for which the ordinary photographic plate is insensitive. Most of those who had experience 30 or even 20 years ago of attempting to sensitize plates to red light would hardly be optimistic of getting any advance here but nevertheless it is just here that important successes have been achieved. One of the highlights of the meeting of the I.A.U. at Stockholm in 1938 was provided by Dr Baade, at a joint meeting for the discussion of galactic structure, when he showed photographs of obscured regions of the sky taken with a new brand of red-sensitive plate. Plates, hypersensitized with ammonia and used with a filter cutting out light of wave-length shorter than 5000 A showed in 75 minutes the faintest stars which could be photographed with fast blue plates in 50 minutes if the colour index was as high as $+0{\cdot}40$. For stars with a higher colour index the red-sensitive plates were relatively faster. In obscured regions of the Milky Way especially towards the galactic centre the advantage of the red-sensitive plates was striking almost beyond what can be expressed in words. The great increase in sensitivity was gained without perceptible increase in chemical fog. Baade stated that on a very conservative estimate one plate showed 800 000 stars to the square degree and that the limit had not been reached with the optical means available. He found that exposure times in the red region could be extended to 5 hours with the Mount Wilson reflectors on an average night before the sky fog equalled that of a 90-minute exposure on a fast blue plate.

The stage was thus set for renewed efforts to resolve the central mass of the Andromeda nebula. The story was told dramatically by our medallist and I repeat it now although it partly overlaps what I have already quoted from a Mount Wilson report.

" It was quite a surprise when plates of the Andromeda nebula, taken at the 100-inch reflector in the fall of 1942, revealed for the first time unmistakable signs of incipient resolution in the hitherto apparently amorphous central region —signs which left no doubt that a comparatively small additional gain in limiting magnitude, of perhaps 0·3–0·5 mag. would bring out the brightest stars in large numbers.

" How to obtain these few additional tenths in limiting magnitude was another question. Certainly there was little hope for any further gain from the blue-sensitive plates hitherto used, because the limit set by sky fog, even under the most favourable conditions, had been reached. However the possibility of success with red-sensitive plates remained. From data accumulated in recent years it is known that the limiting red magnitude which can be reached on ammoniated red-sensitive plates at the 100-inch in reasonable exposure time is close to 20·0,

the limiting photographic magnitude being 21·0. These figures make it clear at once that stars beyond the reach of the blue-sensitive plates can be recorded in the red only if the colour indices are larger than + 1·0—the larger the better."

I need not now go into the details of how the successful plates were secured, about the very restricted range of wave-length used (6300–6700 A) so as to cut out the most troublesome part of the light of the night sky, and the pains taken to neutralize changes of the focus during the long hours of exposure. Suffice it for the present to say that the deed was done and the methods immediately applied to the two companion nebulae M 32 and NGC 205 as well as the Andromeda nebula itself. I cannot refrain from another quotation which shows the difficulty of the observations and the trouble taken by our medallist to check his results :

" Because the resolution of NGC 205 proved so easy in red light, a corresponding test on a fast blue-sensitive plate seemed to be of special interest. The nebula was therefore photographed at the 100-inch on the remarkably fast Eastman 103 a – O emulsion. The exposure time was 90 minutes, which represents about the practical limit of plates of this type. The plate reveals incipient resolution of NGC 205 quite unmistakably, but the prevailing pattern is yet very soft, and the smallest elements are not yet stars but small-scale fluctuations in the stellar distribution. The resulting impression is very irritating to the eye. The nebulosity has lost its amorphous character but nothing definite has yet emerged."

Our medallist proceeded to exploit to the full the red-sensitive plates. They were indeed used in some of the work on novae and supernovae already mentioned. Beautiful photographs have been published of the Crab Nebula in light of wave-lengths 6300–6700 A and 7200–8400 A, the first showing extensive filaments in the outer regions of the nebula and the latter the amorphous region.

The successful resolution of the two companions to the Andromeda nebula which are classified as elliptical nebulae led to the selection of other elliptical nebulae for observation. The expectation that NGC 147 and NGC 185 would prove to be members of the local group of galaxies has been confirmed. Their constitution appears to be intermediate between NGC 205 and the extremely loose stellar systems in Sculptor and Fornax found by Shapley to be members of the local group. This raised to 13 the number of known members of the local group, 3 spiral nebulae, 4 irregular systems and 6 classed as elliptical nebulae. Recently two more systems believed to belong to the local group have been found, this time lying in a direction quite different from the others so that our system with the Magellanic Clouds is in a more central position. These discoveries are tending to give us a quite different conception of the structure of the universe, at least in our neighbourhood. I used to think of a universe constructed of spiral nebulae situated at great distances from one another—distances great compared with their own dimensions. But just as in our own system we have to admit many faint stars at distances small compared with the majority of the naked eye stars so we have to admit many dwarf galaxies amongst the large ones. In the local group we have our own system, two other spirals of absolute magnitude $-14\cdot9$ and $-17\cdot9$; the Magellanic Clouds of absolute magnitudes $-14\cdot5$ and $-15\cdot9$; and the other 8 or 10 systems of absolute magnitude $-10\cdot5$ or a little more. The smaller systems have linear dimensions of the order of 1 kpc, the Andromeda nebula of 13 kpc and our own galaxy at least twice this. The distribution of these galaxies is very uneven, half a dozen being quite near the Andromeda nebula; the two Magellanic Clouds are separated by about two

diameters. The elliptical nebulae in the local group are about 5 magnitudes fainter than the great spirals or Magellanic Clouds. Some of our brighter globular clusters rival the elliptical nebulae in brightness although they have only about one-tenth the linear dimensions.

Before leaving this section of my address I would like to mention that in recent years Dr Baade has taken with the 100-inch reflector an extensive series of photographs of the whole region of the Andromeda nebula over an area $1\frac{1}{2}^\circ \times 5^\circ$ in light of four different ranges of wave-length: ultra-violet, blue, red, and infra-red. Some hundreds of emission patches have been found and it is hoped from radial velocity determinations to learn something of the dynamics of the spiral. The intimate connection between dust, supergiant stars and emission patches should be of significance in the evolution of the system. From a comparison of the photographs it should be possible to form a much better idea of the total contents of the Andromeda nebula, and this should shed light on the composition of our own galaxy.

One of the conceptions for which our medallist is responsible is that different regions of space have contents of one or other of two different types, to which he has given the name of Population I and Population II. Before proceeding to speak about his more recent work I would like to explain this idea to you.

It has long been known that the different types of stars are not uniformly distributed amongst the various groupings of stars. For example, very early-type stars, so numerous amongst the Pleiades, are missing amongst the Hyades. Again, more bright Cepheids are found in our system than stars of the fainter cluster type of variable. This might be attributed to our ability to detect the brighter stars at greater distances. But when the globular clusters were considered, with all the stars at approximately the same distance, the fainter short-period variables showed up in much greater numbers, frequently to the exclusion of the brighter Cepheids altogether. All the bright early-type stars in our system have small motions, while the high-velocity stars are mostly dwarfs. Now the difficulty of resolving the early-type nebulae, even when relatively near, indicated to our medallist that they could not contain any of the early-type stars or the supergiants of late type. The stars of large colour index which he ultimately found in them must be of a type not found in our neighbourhood. He was led to the conclusion that for some reason or other stars of different kinds were evolved in different regions. The high-velocity stars, the stars found in globular clusters, those found in elliptical nebulae and in the central unresolved regions of spiral nebulae he postulated as belonging to Population II, while the stars in our neighbourhood and in the outer arms of the spiral nebulae he described as belonging to Population I. The special characteristic of stars of Population I is that when plotted with absolute magnitude against spectral type or colour index they form the H–R diagram to which we have been accustomed for the last forty years, while the brighter stars of Population II do not fit into this diagram although the fainter stars do. An explanation of the two different kinds of population must be sought in the amount of cosmic material available for their evolution, and must include the fact that stars of both populations may occur in the same region, as in some of the branches of our galaxy.

The Orion nebula is one of the best-known objects in our winter sky. On a dark night it can be seen, even in these islands, with the naked eye, although at best it can be but dimly seen. Most people think of it as an extensive patch of

white light such as it appears on the photographs which are reproduced in so many text-books. When you see it through a telescope you see the patch of light but the outstanding formation is the trapezium—four bright stars close together which have been denoted from the time of Bayer as θ' Orionis. As a great deal of the light from the nebula is from line emission this can be cut out by the use of filters and what is left photographed on plates sensitized to light from the red and infra-red end of the spectrum. When this is done a considerable cluster of stars appears with the 4 bright stars of the trapezium near its centre. This cluster was investigated more than 20 years ago by Trumpler who described it as an open cluster. It has more recently been investigated by Baade and Minkowski, who has been associated with our medallist in much of his work involving spectroscopic observations. At first the Mount Wilson observers found a small cluster of 50–100 stars from photographs taken in light of wave-length 8300–9300 A. This was much less extensive than the cluster found by Trumpler, but more recently, for plates taken in the region 7100–7500 A, they have stated that the area normally filled with the luminous nebulosity is replaced by an area of high stellar density. Apparently the transparency of the Orion nebula for long waves is not restricted to the neighbourhood of the exciting stars but is characteristic of the whole of the excited nebulosity. The transparency decreases with increasing distance from the exciting stars. This fits in with the explanation given earlier from a spectrophotometric study of a number of early-type stars connected with the nebula. It was found for these stars that the selective absorption was much greater for wave-lengths under 6000 A than for those in the region 6000–9000 A. The radiation from the stars may have expelled the smallest dust particles from their neighbourhood and so made it more transparent. Clearly further study of this region may yield results of importance for a better understanding of stellar evolution.

Ever since it has been recognized that the Sun is not at the centre of our galactic system, it has been accepted that the centre must lie in the direction of the Milky Way in Sagittarius. Many things have pointed to this, besides the brightness of the star clouds in that direction. The general distribution of galactic objects has been in accordance with it and an analysis of the radial velocities of bright early-type stars has shown that the Sun is taking part with other stars in revolution about a centre in the same direction. After the Andromeda nebula had been recognized as a spiral nebula, astronomers had got used to the idea that our own galaxy might be of a similar nature. It was generally considered, however, that the great congestion of stellar and nebular material towards the centre together with vast areas of obscuration did not give us any hope of penetrating into the nucleus. Observations towards the densest parts of the galaxy were generally directed towards finding " windows " through which more remote objects might be observed. Our medallist had been struck by the great brightness of the Sagittarius cloud which indicated that obscuration in that direction might be well below the average. His early photographs with red-sensitive plates had indicated high stellar density. He knew that the outer arms of the Andromeda nebula contained stars of Population I, such as were to be found in our neighbourhood, while in the central region stars were of Population II. If the resemblance of our galaxy to the Andromeda nebula was complete we should find stars of Population II in the Sagittarius cloud. So he decided to investigate with red-sensitive plates the types of stars to be found there.

He was rewarded by the discovery of a large number of variable stars—many times more than he had found in the other Milky Way fields which he had investigated. Detailed examination of the variables indicated that those found in the Sagittarius cloud were, like those in the central region of the Andromeda nebula, of Type II while stars in general found in the Milky Way were, like those in the spiral arms of the Andromeda nebula, of Type I. This agreement was for all types of stars that could be investigated, in Type II more than half the variables were of the cluster type, in Type I half were eclipsing variables and only a few per cent cluster type. The distance modulus as well as that of the globular cluster NGC 6522 involved in it was about 17·3. Allowing for a colour excess of 0·37 involving a correction to the distance modulus of 2·6, our medallist reduced the distance modulus to 14·7. This indicates a distance of about 9 kiloparsecs, close to the value generally accepted for the centre of our galaxy. Our medallist therefore concluded that the Galaxy is as to the nature of its contents very similar to the Andromeda nebula, that is to say an intermediate spiral of type Sb, and that we are situated about 9 kiloparsecs from the centre.

At the beginning of this address I announced that our medal had been awarded for observational work on galactic and extragalactic objects. Apart from the reference to observational work the citation has given me very wide scope. The nature of the objects is not specified and I am allowed to range over distances measured in kiloparsecs and millions of light years. I am also allowed to speak about our medallist's work on objects situated at the relatively minute distances to which light can come and go in a matter of minutes, distances usually measured in the most fundamental of all our units—the astronomical unit. Minor planets have been described, by unsympathetic writers, as the vermin of the solar system and I once heard a story—I do not vouch for its accuracy—that it was suggested in this room that it be considered a crime punishable by fine and imprisonment to discover any more. If it be a crime your Council has condoned it in making the present award. As I have already mentioned, our medallist did some work at Hamburg on the minor planets, and in the U.S.A. he has not forgotten them. On a plate taken with the large Schmidt telescope on Palomar he found the trail of a most unusual object. The antics of this body, to which the name of Icarus has been given, were described to you last year by Dr Herrick. Our medallist has estimated that there may be 44 000 minor planets down to the 19th magnitude and observable with the Schmidt telescope. This estimate he made from 37 trails found on 21 plates exposed for $1\frac{1}{2}$ to 2 hours on a region near the ecliptic, making careful estimation of the factor by which the 37 had to be multiplied. He has mercifully refrained from trying to clinch his argument by locating them all. There are too few astronomers, too few telescopes, too few calculating machines to cope with so many.

The estimation of great distances depends on accurate determinations of (1) apparent magnitudes of individual objects, (2) absolute magnitudes of these objects, (3) absorption of light in space.

About (1) I have already stated that there are no insuperable difficulties, but that it is so easy to be careless in the hunt for quick results. In nearly all Baade's papers I have been struck by the attention he has given to the magnitudes of comparison stars. There is a continuous reference to the setting up of accurate standards on the scale of the north polar sequence. It is well known that at

Mount Wilson Dr F. H. Seares laboured for many years on the very important but non-spectacular field of exact photometry. I can think of no better testimonial to our medallist's reliability in this connection than the fact that he was selected to succeed Dr Seares in this work. He has now in hand a plan to set up standard magnitudes down to the faintest stars observable with the Hale telescope. The standards will be established in 6 Kapteyn Areas, separated by 4 hours in R.A., 3 of them in Dec. $+30^\circ$ and the other 3 in Dec. $+15^\circ$. Once they are available they will be a boon to astronomers in the southern as well as the northern hemisphere. The work is simplified by using photoelectric methods to make direct comparisons with the polar standards from magnitude 6 to 17 or thereabouts. It is good to know that this part of the work is being undertaken by Dr Stebbins and Dr Whitford. From magnitude 16 or 17 the scales will be extended photographically to the faintest observable stars by our medallist.

The absolute magnitudes used in determining the distances of very remote objects depend at present fundamentally on those of the classical Cepheids. We cannot be satisfied with this position. The mean parallax of a distant group of stars can be determined from the proper motions. Thirty years ago the best proper motions available were used, but for all the Cepheids the motions were small and relatively uncertain. It was therefore decided at both McCormick and Mount Wilson Observatories to undertake new determinations from photographs taken at an interval of 20 years or more. Unfortunately it has now to be admitted that the motions of the Cepheids are no more than those of the comparison stars so that there is little hope of a definitive result from the parallactic motions. A new method of settling the zero point is therefore required and is being planned as one of the earlier pieces of observational work with the Hale telescope. We know from direct trigonometric determination the distances of a large number of stars of types F to K with very considerable accuracy. For these stars we can therefore calculate reliable absolute magnitudes. Our medallist hopes to observe such stars in some of the distant systems. The observations will not be easy as they will involve not only accurate apparent magnitudes but also spectral classification or at least colour indices of very faint stars in clusters. Once this is done the distance of the systems can be deduced and then will follow the absolute magnitudes not only of the Cepheids but of any other objects in the systems. This seems to me by far the most hopeful method of determining the absolute magnitudes of the brightest stars, and these will then become available for the determination of distances reckoned in kiloparsecs.

As to the lack of transparency of space, that remains a challenge but also a means of determining something about the contents of interstellar space.

This account of our medallist's work is far from complete. He has published too much for me to review it all today. We also know that he has done much work still unpublished, and that he has still many valuable observations awaiting discussion. We look forward to seeing the results made available to us. At the same time he has embarked on an ambitious programme to extend his results to more distant objects and most important of all to build anew on a firmer foundation an accurate distance scale. In this work he has the good wishes of us all and indeed of astronomers everywhere. It is with the greatest pleasure that I express to him on your behalf on this occasion our thanks for what he has already accomplished and our best wishes for his future work.

ELECTION OF OFFICERS AND COUNCIL

President

J. Jackson, Esq., C.B.E., M.A., D.Sc., F.R.S.

Vice-Presidents

Miss Flora M. McBain, M.A., Principal Scientific Officer, H.M. Nautical Almanac Office.
W. H. McCrea, Esq., M.A., Ph.D., F.R.S., Professor of Mathematics, London University (Royal Holloway College).
H. H. Plaskett, Esq., M.A., F.R.S., Savilian Professor of Astronomy, Oxford University.
D. H. Sadler, Esq., O.B.E., M.A., Superintendent, H.M. Nautical Almanac Office.

Treasurer

L. M. Milne-Thomson, Esq., C.B.E., M.A., F.R.S.E., Professor of Mathematics, Royal Naval College, Greenwich.

Secretaries

C. W. Allen, Esq., D.Sc., Perren Professor of Astronomy in the University of London.
A. Hunter, Esq., Ph.D., D.I.C., Principal Scientific Officer, Royal Observatory, Greenwich.

Foreign Secretary

F. J. M. Stratton, Esq., D.S.O., O.B.E., T.D., D.L., LL.D., F.R.S., Emeritus Professor of Astrophysics in the University of Cambridge.

Council

A. Armitage, Esq., M.Sc., Ph.D., Lecturer in History and Philosophy of Science, University College, London.
H. Bondi, Esq., M.A., Professor of Mathematics in the University of London.
Mrs. E. M. Burbidge, B.Sc., Ph.D.
E. H. Collinson, Esq.
T. G. Cowling, Esq., M.A., D.Phil., F.R.S., Professor of Applied Mathematics, University of Leeds.
V. C. A. Ferraro, Esq., Ph.D., Professor of Mathematics in the University of London.
Sir Harold Spencer Jones, M.A., Sc.D., F.R.S., Astronomer Royal.
A. C. B. Lovell, Esq., O.B.E., Ph.D., F.Inst.P., Professor of Radio Astronomy in the University of Manchester.
R. A. Lyttleton, Esq., M.A., Ph.D., Lecturer in Mathematics, University of Cambridge; *Geophysical Secretary*.
R. W. B. Pearse, Esq., Ph.D., D.Sc., A.R.C.S., Assistant Professor and Reader in Spectroscopy, Imperial College of Science and Technology, London.
J. G. Porter, Esq., B.Sc., Ph.D., F.C.S., Principal Scientific Officer, H.M. Nautical Almanac Office.
S. K. Runcorn, Esq., M.A., Ph.D., Assistant Director of Research in Geophysics, University of Cambridge.

CONTENTS

Contents

PROCEEDINGS OF OBSERVATORIES :

Printed in London by Taylor & Francis, Ltd., 1954 December